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PURIFICATION OF THE WATER-SUPPLIES OF CITIES.

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[*A Lecture delivered before the* FRANKLIN INSTITUTE, *Thursday, December 23, 1886.*]

THE LECTURER was introduced by Dr. Wahl, the Secretary of the INSTITUTE, and spoke as follows:

ACTING UNDER INSTRUCTIONS from the Aqueduct Boards of Newark and Jersey City, I spent the past summer in examining the water-supplies of the large cities in England and Scotland. Many of these cities have already passed through crises in the history of their water-supplies, similar to those at present agitating American communities. It is of the remedies which they have adopted, and of the pressing needs of Philadelphia, Albany, Newark, Jersey City, Wilmington, Washington and other places, that I propose to speak this evening.

Our modern manufacturing towns increase in population with such rapidity that they soon find their local sources of water-supply insufficient in quantity, and dangerous to health from pollution by

sewage and factory waste. Then follows a more or less prolonged period of bitter controversy. It matters not how plain the fact of gross pollution may be; the fact is denied. In case the chemical testimony agrees with that of the senses, and water which is dirty, foul-smelling and bad-tasting, is found by the chemist to be impure, his honesty and ability are assailed. Either his results are declared false, or it is asserted that they mean just the reverse of what he himself says. Other experts are employed, and the local water-supply, though it may contain the sewage of 10,000 or 100,000 people, is joyfully discovered to be extremely pure, and second in purity to none in the country. But at last, after years of denial, during which the public health has severely suffered, the fact of pollution is admitted, and the community resorts to one or more of the three following remedies:

(1.) It abandons local for remote sources, such as springs, lakes, rivers, or areas of upland drainage.

(2.) It sinks artesian wells, or deep wells, or subterranean galleries.

(3.) It purifies the polluted local supply.

In the study of this subject, there is no source of information more valuable than the blue books containing the minutes of inquiry before the Royal Commissions of 1851 and 1868 upon the supply of London. It is there stated that at first London drew its supply directly from the Thames, where it flowed through the town, at London Bridge. This was in 1581, and a century later (1691) the Thames was again drawn upon at Charing Cross, and this intake remained in use as late as 1829. Again, in 1723, the Chelsea Water Works were established, and in 1785 those at Lambeth. Whilst some part of the water-supply was derived from springs in the chalk formation at Chadwell (brought in through a canal called the New River, in 1613), and another part from the river Lee (introduced by the East London Water Works Company, in 1806), yet as late as the year 1829, the metropolis was principally supplied by water taken from the Thames within the reach of the tidal flow. But in 1829, a Royal Commission, consisting of Telford, Brande and Roget, was appointed to inquire into "the description, the quality and the salubrity" of the water. They reported "that the Thames water, when free from extraneous substances, was in a state of considerable purity; but as it

approached the metropolis it became loaded with a quantity of filth which rendered it disgusting. It appeared, however, that a very considerable part, if not the whole, of this extraneous matter, might be removed by filtration through sand, and the Commission decided that it was perfectly possible to filter the whole supply with the requisite rapidity and within reasonable limits of expense." Stimulated by this report, and alarmed, probably, at the prospect of a sweeping change of the sources of supply, the companies directed their attention to the purification of the water by filtration. It was soon found that the only appropriate material for mechanical filtration on a large scale, was fine sand; but the great practical difficulty was to prevent the sand from becoming clogged, and to find an easy, practical and cheap method for its renewal. After long experimentation, a means was discovered of getting over these difficulties. It was found that by far the greater quantity of the impurities was held in suspension by the agitation and motion of the water, and that if it was allowed to stand for some time at perfect rest, in a reservoir, the heavier and grosser particles were deposited by simple subsidence, leaving only a small proportion of lighter and finer matters to be dealt with by filtration. It was also found that when the water was allowed to filter downwards through a porous bed of sand, held up in its place by underlying layers of coarse gravel, the dirt did not penetrate into its mass, but was stopped at its upper surface, so that the whole cleaning operation necessary was to scrape this surface off to a slight thickness, and, when it had become too much diminished, to put on fresh sand.

In accordance with these suggestions, the first large filter, which had an area of one acre, was put into use by the Chelsea Company, in 1829.* It worked well, so well indeed, that it led to the well-nigh universal practice of filtration in England. Our failure to do the same in this country, shows that in this respect we are behind the age.

But about the time of this first use of filters in England, the disturbing ideas of modern sanitary science took their rise; that unspeakable abomination, the domestic cesspool attached to a city house, began to be abolished; drainage and sewerage works were

* Royal Comm. Water-Supply, 1868.

established, and the amount of impurities carried to and fro under London Bridge was increased enormously.

This agitation kept on growing, until, in the year 1834, the engineer, Mr. Telford, recommended that the Thames should be abandoned. This was not done, but in 1851, a Royal Commission, consisting of Profs. Graham, Miller and Hofmann, recommended that while the supply should still be drawn from the Thames, the points of intake should be removed above the influence of tidal flow (*i. e.*, above Teddington Lock). They made other recommendations, which were incorporated into an Act, passed in 1852, regulating the water-supply of the metropolis. In this act, the two clauses of greatest significance to us, are, (1): That every storage reservoir within five miles of St. Paul's should be covered; and (2), That all water supplied for domestic use *should be effectually filtered, unless it is pumped from wells direct into covered reservoirs*.

A mere statement of the law, which was passed after a quarter of a century of discussion by the most eminent engineers, chemists and law-makers of England, is a more emphatic testimony to the fundamental importance of the provisions therein contained, than any argument I am able to make.

This law led to certain results throughout England, which I trust will become universal. These are:

(1.) The education of public opinion to such a point as to demand sources of city water-supply, actually and visibly free from pollution. The wealthiest communities like Glasgow, Manchester and Liverpool, have deemed it a wise investment of great sums of money to obtain sources absolutely free from suspicion and reproach.

(2.) The construction of large, and in some cases vast, reservoirs with the object, not merely of safety, but also of allowing opportunity for the dissolved organic matters to oxidize, or to be carried by subsidence along with the suspended mineral matters to the bottom.

(3.) Effectual filtration. And it should be noted, that when the Act of 1851 required the London companies to filter the water, under very heavy penalties, the water referred to was that taken from the Thames above Teddington Lock, which water the Commission had previously found to be "perfectly wholesome,

palatable and agreeable." Still more striking instances of the estimate put upon filtration, as a process indispensable to the excellence of city water-supply, were frequently brought under my personal observation, and some I shall mention later.

(4.) The preservation of the water, after it has been filtered, in covered storage reservoirs.

The good effects of the Act of 1851 speedily became apparent. The water companies expended £2,500,000, with the result, according to the examinations of Prof. Hofmann and Mr. Blyth, made in 1856, of bringing about "a very positive and considerable diminution in the amount of organic matter. This, though doubtless due chiefly to the removal of the intake to a point above the tideway of the Thames, was also attributed in great degree to the considerable improvement which had taken place in the collection, filtration, and general management of the supply of water."

But, fortunately, the public was not satisfied. In pursuance of the recommendations of the Royal Commission of 1865, on the pollution of rivers, the admission of sewage or any other offensive or injurious matter into the Thames, or into any tributary stream or water-course within three miles of its junction with the Thames, was declared illegal, with heavy penalties. In 1866, 5,596 lives were destroyed in London by cholera, and although this visitation was subsequently attributed to the polluted water of the Ravensbourne and the foul unfiltered water from the reservoirs at Old Ford on the river Lee, yet it so alarmed the community that the Commission of 1866 was appointed to make a far more extended inquiry than ever before, and to ascertain what supply of unpolluted and wholesome water could be obtained, by collecting and storing water in the high grounds of England and Wales, either by the aid of natural lakes or by artificial reservoirs, at a sufficient elevation for the supply of London and the principal towns of England. Now it is a well-known fact that the recommendations of the very distinguished engineers came to naught, so far as London was concerned, though they are at present bearing fruit in connection with Manchester and Liverpool.

It is well worth our while to inquire why such was the case. Mr. Bateman's plan was to bring the waters collected from the drainage areas at the head of the river Severn in Wales (including the drainage area of the Vyrnwy) by gravitation through an

aqueduct 180 miles in length, and capable of conveying 230,000,000 gallons per diem. Messrs. Hemans and Hassard proposed to bring the waters of Lakes Thirlmere, Ullswater and Haweswater, through conduits, tunnels and pipes equivalent in their carrying-capacity to a river 30 feet wide and 10 feet deep, over a length of 270 miles. These plans, which were considered the best, were reported upon unfavorably, principally on account of the cost, the estimated expense of Mr. Bateman's scheme being £55,000,000, and that of the Cumberland lake scheme still greater.

This report decided the future supply of the metropolis, and confined it to local sources The supply from Lake Thirlmere has already been appropriated by the city of Manchester. The water will be brought in a tunnel nine feet square to the reservoirs at Prestwich, on one side of Manchester, a distance of ninety-five miles, and continued thence to reservoirs on the other side of Manchester, a distance of 110 miles. Mr. Hill, the engineer of the new supply, informed me that the first 10,000,000 gallons are estimated to cost £2,000,000, inasmuch as the tunnels of full size are to be constructed at once, and connected by a forty-inch iron pipe where siphons are necessary. The second 10,000,000 gallons are estimated to cost only £400,000. The land damages to persons living around the lake and along the tunnel are £225,000.

The supply from Vyrnwy Lake has been appropriated by Liverpool. This artificial lake is to be created by a dam, which, at its top, will have a length of 1,173 feet, and will rise to a height of 144 feet above the bed-rock and 84 feet above the bed of the existing river. Its length will be 4¾ miles, its area 1,165 acres, and its greatest depth of water about 84 feet. The aqueduct from the lake to the existing Prescot Reservoir, nine miles east of the Liverpool Town Hall, is sixty-eight miles. It will consist mainly of tunnels, through which the ultimate supply of 40,000,000 gallons a day may be passed without filling them, and of three lines of pipes, each having an internal diameter varying according to the fall of the sections from thirty-nine to forty-two inches. All this water from the Welsh mountains will be subjected to filtration through sand-filters, the Oswestry reservoir and the three reservoirs for filtered water having an aggregate storage capacity of 54,549,500 gallons.

In one very important particular, the Commission of 1866 was

certainly in error. It thought a probable increase of population to 4,500.000 or 5,000,000 would have to be provided for, and a maximum daily supply of 200,000,000 gallons, though the time for such an extended provision would be very remote. As a matter of fact, the population supplied by the companies in May of this year, was 5,274,542, and the average daily supply during the month was 160,388,316 gallons. Of this, more than half, or 82,366,466 gallons, came from the Thames, and the balance from the river Lee, and from certain chalk springs in the valleys of the Lee and Thames, and from twenty-one deep wells sunk into the chalk formation to the north and south of London. There are fifty-four *subsiding reservoirs for unfiltered water*, with an area of 465 acres, and an available capacity of 1,290,100,000 gallons, and fifty-three *covered reservoirs for storage of the water after filtration*, with a capacity of 160,002,000 gallons. The number of filter-beds is ninety-nine, with an area of ninety-eight acres. Of this surface, ninety-two acres were cleansed during the month of May, some of the filter-beds being cleansed once and partly gone over again during the month. The maximum permissible rate of filtration is two feet per hour and per square foot of surface, but as a matter of fact, the actual rate in the month of May last was generally much smaller than this, some filters passing only one and one-third feet. The construction of the filters varies greatly, the top layer, however, being in all cases fine sand, in depth from two to four and one-half feet.

From the published analyses it appears that the quality of the water supplied to London is usually satisfactory, though at times results are obtained adverse to that portion of it which is derived from the Thames. The population of the drainage area of the Thames is very large, and although the towns located therein are compelled to purify their sewage, yet much polluting material from them and from the floating population on the river, finds its way into the river.

Leaving for the present the history of the largest experiments hitherto made in the way of purification of a polluted water-supply, I shall ask your attention more particularly to the methods by which such purification may be effected.

Artificial Aëration.—One of the easiest and most inexpensive

methods of improving the quality of water, is by means of artificial aëration. The importance of natural aëration has been recognized from time immemorial, and the effect of tumbling down natural falls and rapids, passing over artificial dams, and of agitation by winds and storms, in keeping water lively and sweet, is too well known to need more than passing mention. It is of especial interest to us that this mode of improving water was first applied to city water-supply in consequence of the extremely offensive taste and odor of the Schuylkill water in January and February, 1883. The fact that the analyses revealed the presence of a large amount of sewage in the Fairmount water, did not explain its peculiar offensiveness at that season, for there have been times, before and since, when it contained even more sewage and was not so unpalatable. But it appeared to me very noteworthy that the oxygen which ought to be present in a state of solution, was largely deficient. Much of it had been used up in the oxidation of the sewage, and the river, being ice-bound from its source to Fairmount Dam, had no opportunity of taking from the atmosphere sufficient oxygen to replace that which had been lost.

Reflecting upon these facts, I thought it worth while to try the effect of submitting the disgusting samples from Fairmount Pool to artificial aëration. I found that they not only took up from the air forced through them, the oxygen they lacked, but also that much of the sewage to which their offensiveness was due, was destroyed. These experiments suggested to me the idea of pumping air into the lower ends of the mains at the pumping-stations. This way of introducing the air was not only the easiest and simplest, but it also afforded an opportunity of placing the mixture of air and water under a maximum pressure. Air, as is well known, consists of twenty-one parts by volume of oxygen and seventy-nine parts of nitrogen; but the oxygen is more soluble in water than the nitrogen, and therefore the greater the pressure to which a mixture of air and water is subjected, the larger is the relative amount of oxygen made to enter into solution.

The study of the subject received fresh impetus from the condition of the water-supply of Hoboken in the latter part of July, 1884. At that time, the oxygen in a number of samples from the Hackensack River, whence the supply of Hoboken is derived, fell to 3·87 c. c. per litre, and the total dissolved gases to 14·93 c. c.

Contemporaneously, the same waters, when impounded in the reservoir, became covered with a scum several inches in thickness, consisting largely of *Oscillariæ*. These quickly died, and yielded up a dark blue coloring matter (*the Phococyan of Cohn*). Finally, this great accumulation of vegetable growth passed into a state of active decomposition, attended with the formation of white foam, and the liberation of large volumes of carbonic acid and other gases. The water for ten days previous had been too nauseous to drink, but the whole succession of phenomena above described took place within twenty-four hours, the vast development of algæ, their breaking up with evolution of green and blue coloring matter, and their final decomposition occurring with astonishing rapidity. The entire reservoir had the appearance of an enormous dyeing vat, covered with dark green and blue dye-stuffs.

A repetition of the same disastrous sequence of events was threatened on September 14th, when the percentage of dissolved oxygen fell to four cubic centimetres, and at the same time a growth of algæ began in the reservoir. But meanwhile arrangements had been perfected in anticipation of this catastrophe, and by pumping air under pressure into the mains, the percentage of total dissolved gases was raised from 15·9 cubic centimetres to 21·2 cubic centimetres. The green scum on the reservoir disappeared, and the taste and smell of the drinking-water became satisfactory.

In November, 1884, a preliminary experiment was instituted at the Fairmount Pumping Station, an air-pump being attached to the main at that point. The aërated water was pumped into the Corinthian Basin through the forty-eight-inch main, a distance of 3,000 feet. The results of this experiment were so encouraging, that the Chief-Engineer, Col. Ludlow, obtained air-compressors for all the pumping-stations. At only one of them, however, has the process been applied, namely, at Belmont, the other mains being too leaky to permit of its being used.

At this station, the water has been charged with twenty per cent. of its volume of air, and the change in composition thereby effected is strikingly illustrated in the following results, which give the composition of the water before it enters the pumping-main, and as it is discharged therefrom.

	PARTS PER 100,000.	
	Non-aerated.	*Aerated.*
Free ammonia,	0·017	0·004
Albuminoid ammonia,	0·011	0·007
Oxygen required to oxidize organic substances,	0·133	0·117
Nitrous acid,	0·0008	none
Nitric acid,	0·45	0·54
Total solids,	9·00	8·70

It will be seen that the albuminoid ammonia has diminished nearly forty per cent.; and, what is the most noteworthy feature of all, the nitrous acid has undergone complete oxidation, none being present in the aërated sample. At the same time, by oxidation of the nitrogenous portions of the organic matter, the nitric acid has been increased twenty per cent.; and by oxidation of the organic constituents in general, the total solids have been diminished from nine parts per 100,000, to 8·7 parts.

The process has now been applied to the entire water-supply of Hoboken, amounting to 4,000,000 gallons per diem, for more than two years, and during this time the unpleasant taste which caused its first application, has never reappeared.

Similar experience in Brooklyn has caused the process to be used in connection with the water obtained from driven wells. This driven well water has been used in the Greenwood Cemetery to feed a number of artificial lakes arranged to beautify the grounds. Last summer, I was asked to examine the water in the reservoir into which the driven well water is first pumped, and to devise a means if possible for preventing the enormous growth of plants therein. The growth, on examination, proved to be diatomaceæ, particularly of the species *Navicula viridis*, and the green vegetable substance which by its decay rendered the water offensive, was the slime secreted by these diatoms. Two facts were prominent. The one was that the diatoms could be made to grow very rapidly when exposed in open jars to sunlight; the other, that the water of the reservoir was very deficient in dissolved oxygen. It contained only 2·32 cubic centimetres of oxygen in the litre, and the enormous amount of 4·97 cubic centimetres of carbonic acid. I advised the covering of the reservoirs to exclude sunlight. The authorities were opposed to so doing, because it destroyed the very result aimed at in providing the reservoir and ponds, which was to beautify the park. Then I advised the use

of an air-compressor. This was installed, and the result is given in the following letter from the consulting engineer:

NOVEMBER 27, 1886.

DR. ALBERT R. LEEDS:

Dear Sir:—In answer to your inquiry concerning the trouble at the Greenwood Cemetery reservoir, I would state that the water, fresh from driven wells, when delivered into the reservoir, began to develop decaying vegetation, which in a short time rendered the water offensive to taste and smell; that immediately on receipt of your report and recommendation, last June, I set up an ordinary compressor, and pumped air into the mains under a pressure of about eighty pounds to the square inch, allowing it to escape through the reservoir with this result. At first there was no perceptible effect, but upon increasing the amount of air supplied to the water, to the extent of about ten per cent. of the free air to an equal volume of water, the trouble in the reservoir disappeared. Since that time air has been freely supplied whenever there appeared to be any recurrence of the growth of vegetation in the reservoir, and there has been no return of the offensive taste and smell. Respectfully submitted,

CHAS. B. BRUSH,
Con. Eng. Greenwood Cemetery.

Covered Reservoirs.—In May of this year, the water from the driven wells supplying the city of Jamestown, in Western New York, was similarly affected, the reservoir containing several species of diatomaceæ, among which the *Cocconema Lanceolata* was the most abundant. Certain of the protoccaceæ, especially various species of Scenedesmus and certain genera of Zygnemaceæ, including different species of Spirogyra, were also present. The water in the driven wells (May 22d) had a temperature of only 48°, but that in the reservoir was over 80°, and the development of the spores in the deep-well water was correspondingly rapid. The suggestion to cover the reservoir was carried out in this case, and the aquatic plants disappeared. Similar troubles, and the development of a variety of odors chronicled as "fishy," "pig-pen," "cucumber," and the like, have been reported as affecting, at one time or another, the water-supplies of most of our towns.

There is good reason to suppose that these complaints will continue as long as water, which on standing has lost much of its dissolved oxygen and has become stagnant, is exposed to our burning suns and allowed to rise to a temperature of 70° and upwards, in uncovered reservoirs. Either it should be covered, so as to exclude light, and kept cool, or, if its temperature is allowed to

rise above 70° and it is exposed to the sun, it should be charged with air and kept moving.

Storage and Subsiding Reservoirs.—The development of aquatic growth, and the nauseous tastes and smells arising from its decay, have probably had a discouraging influence upon the construction of large subsiding reservoirs in our own country. In many cities, as in New York and Philadelphia, the small storage capacity has been for years the cause of most serious apprehension. The new works now in progress in connection with the Croton Aqueduct will, it is hoped, overcome this danger, so far as New York is concerned. I noted, however, with great interest, that Mr. Worthen, in the course of his examination before the commission charged with providing a more abundant supply for the metropolis, made the significant remark, in relation to the great new reservoir at Quaker Dam, which will hold 3,600,000,000 gallons, that *stagnant water would not keep.* In England, this difficulty is sometimes, though rarely, encountered. I asked Mr. Wood, the City Engineer of Leeds, whether the English reservoirs are injuriously affected by vegetation. He said that trouble from this source seldom occurred, but when it did occur it was owing to the growth of the American weed. The particular kind of weed he referred to was not so common as its name would appear to indicate, and I never saw it. The great benefit due to storage and subsidence was strikingly exemplified in the case of the city above referred to. Its water-supply is taken from the drainage area of the small river Washburn, at a distance of about ten miles from the city. On this stream are located three impounding reservoirs, and their waters are carried by gravity into the Eccup Reservoir, an artificial lake a mile long and holding 1,400,000,000 gallons. This supply, without addition, is adequate for the consumption of 10,000,000 gallons per diem for nearly five months. But this safeguard is only a part of the advantage due to the large size of the reservoir. For the water is made to enter at the bottom near the great dam forming one end of this artificial lake, and fifty-two feet below the surface. It then travels the entire length of the lake and is taken out by a bell supported on masonry piers, the lip of the bell being 15 feet below the surface and 23 feet above the bottom. During its months of

passage, not only nearly perfect sedimentation of earthy particles occurs, but, by a process of natural oxidation the peaty color is bleached out. Though such is the case, all the water is subsequently filtered, seven filter-beds being adequate, and finally stored in covered reservoirs. These reservoirs are made with inverts of masonry, upon which walls are built, capped by arches, the latter being covered with earth and handsome lawns.

It is not improbable that the difficulties, which we encounter in America from the long-continued heat of summer, may lead to remedies appropriate to our peculiar needs. I have already alluded to the advantage derived from first bringing the percentage of oxygen to the highest possible point, in delaying or preventing that condition of oxygen-poverty, with its resultant growths, which we recognize as stagnation. During the warmer months, reservoirs could be provided with such a covering as might be thrown out of use when winter came on with the accompaniment of crushing weights of snow. I saw at Manchester, Bradford, Buxton and many other towns in England, subsiding reservoirs arranged to effect a subsidence of the sludge or coagulum, which is produced when town sewage is treated with lime. These reservoirs are built with vertical partitions, so that the water flows over the top of the first and under the bottom of the second, and over the top of the third, and so on through sometimes as many as twelve compartments. Where the town sewage does not contain dye-stuffs, as at Buxton, the water coming out of the last compartment is frequently as sparkling as spring-water. The construction of subsiding reservoirs for water-storage in a similar manner, would facilitate cleansing, inasmuch as the greater part of the silt would be deposited in the first and second compartments, and a constant onward movement of the water without a disturbing current would be obtained, permitting of subsidence, while at the same time preventing stagnation.

Filtration.—Up to the present time no material has been found, which is practically available for filtration on a large scale, except fine sand. Sponge, coke, animal and wood charcoal, porous brick, carbide of iron, spongy iron, and many other materials have been tried, but with the result as above stated. When metallic iron is used excellent results are obtained, through its chemical action as

a carrier of oxygen to the organic matters which are thereby oxidized and destroyed, but the water even then must be subsequently filtered through sand.

Until quite recently, it has been supposed that the main benefit of sand-filtration is in the removal of suspended mud and dirt, the amount of organic impurities thereby removed being small. But since Pasteur discovered that the micro-organisms, which are supposed by some to be the specific germs of disease, may be completely arrested by filtration through a thin porous plate, a great revolution of opinion has been effected. In his report for the month of May last, Dr. Frankland states that the unfiltered Thames water yielded by the method of gelatine-peptone culture, 4,800 colonies of microbes per cubic centimetre of water. After passage through sand-filters at Chelsea, it yielded only fifty-nine colonies, and through those of West Middlesex only nineteen colonies. This is indeed astonishing, and the more so when the remarkably pure water in the deep chalk-wells of Kent yielded eight colonies, and the same water by the time it reached its point of supply had increased in its number of micro-organisms, until 101 colonies were obtained in the culture liquid.

At the present time American engineers regard it impracticable to introduce the English system of sand-filters, on account of the great expense of operating them. This has been variously estimated at from $2.50 to $5 per day for each million gallons filtered, exclusive of first cost and interest. Such being the case, I need not go into a statement of the reasons why the few which have been actually brought into use in this country have been so little successful. The conviction appears to be generally entertained that American ingenuity must discover some method by which mechanical arrangements may take the place of the cumbrous English system, and dispense with the very considerable manual labor required in cleansing. Many contrivances have been brought forward, but they are crude, or have complicated systems of pipes for reversals of the current, or are wasteful in the use of filtered water for cleansing. Recently, however, an extremely simple device has been proposed, which is yielding excellent results. As is well known, the efficient part of a filter-bed is the top layer of sand, which need not be more than two feet in thickness. At Poughkeepsie, on the Hudson River, this two feet of sand rests on four

feet of gravel and stone, which are provided merely to support the sand and to afford channels for the filtered water to drain away. This gravel and stone are replaced in the device I have alluded to, the National Filter, by a system of double pipes which are perforated and the annular space between the perforated pipes filled in with fine quartz gravel. The filtered water runs out through these double pipes, while the sand is arrested. By another simple arrangement the manual labor requisite to clean the deposit of dirt from the upper surface is dispensed with. A system of perforated pipes is laid at a distance of six inches below the surface. When it is necessary to cleanse the filter a reverse current of filtered water is sent upward under pressure through these pipes and the impurities are washed off and floated away.

Damage by waste.—The statistics of water-distribution in our American cities show that from one-third to one-half of the water is wasted, not used. Less importance seems to be attached to dirty and unwholesome water, provided there is enough of it, than to controlling dishonest waste and expending the money thus saved in improving the quality of the supply. Until such waste is stopped by metering and fines, there will be little popular sympathy or support for movements intended either to purify and filter the water at present used, or to go ninety miles to get water, one-half of which will subsequently be thrown away.

PROPOSED IMPROVEMENTS IN THE PORT OF HAVRE AND THE ESTUARY OF THE SEINE.—In order that the French ports may hold their position against their rivals on the Continent, the entrance of the Seine must be improved. With this object the following works are proposed: To prolong the dikes as far as Houfleur, to close by a mole the two channels which exist near Villerville, and thus to place Havre at the end of a narrow neck between the sea and the great estuary of the Seine. The Seine dikes would terminate at Rouen, and the channel of the river would remain fixed under the jetties of Houlfleur.—*Mem. de la Soc Ingén Civils, April, 1886.*

A NEW ODONTOGRAPH.

BY GEORGE B. GRANT, Boston, Mass.

My object is to explain the construction and operation of an odontograph, or rather, an odontographic method, which is not only arranged with special reference to convenience and ease of operation, but which is also as accurate as can be desired for all ordinary purposes of construction or drafting.

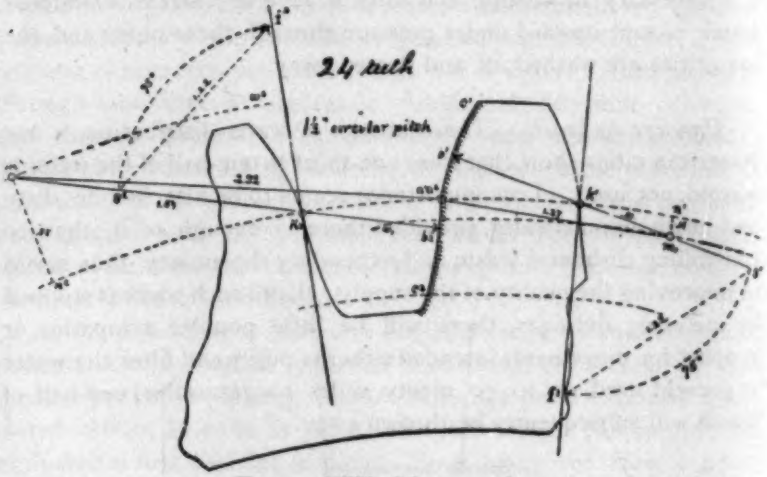

FIG. 1. Willis Odontograph.

In my business, which is specially devoted to the construction of gearing, I formerly had frequent occasion to make use of the well-known Willis odontograph, which has practically been the only one in use for thirty years past.

When using this instrument, the method, as illustrated by *Fig. 1*, is as follows: (1.) The pitch circle is divided off for the pitch points. (2.) A radius is drawn to the pitch circle. (3.) The instrument is laid on the radius. (4.) The positions on the instrument, of the centres, are found by the use of a table. (5.) Circles are drawn through the centres. (6.) The tooth-curves are all drawn in from centres on the centre-circles.

It occurred to me, after wading through this process many times, that much of the work could be got rid of by calculating the

results of the process and arranging them in a table. The real object in view, in the process outlined above, is to get the positions of the circles that contain the centres, and the lengths to set up on the dividers when drawing the tooth-curves. I constructed and for a time used a table giving the distances $m^1\ n^1$ and $m^2\ n^2$ of the circles of centres, and the radii $a^1\ m^1$ and $a^2\ m^2$ for the tooth curves. The result was that much of the labor was avoided and the accuracy of the result greatly improved. It is a work of great skill to so handle the Willis instrument that the same example will give the same result when the operation is repeated, while the use of the table will give uniform results without trouble. The

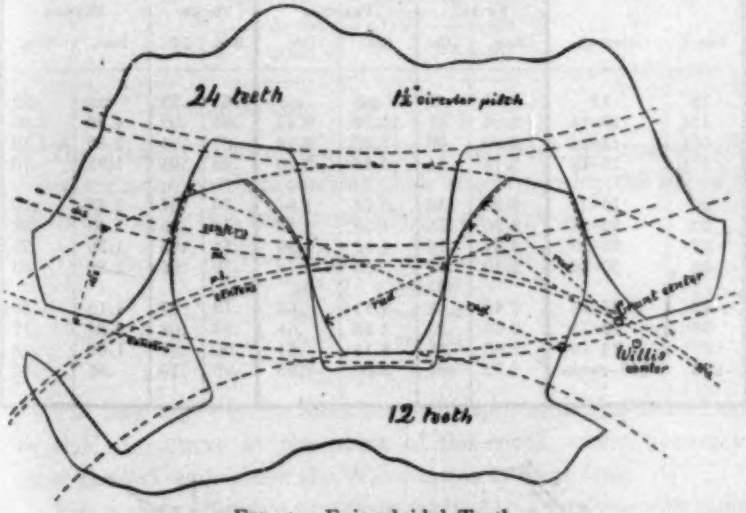

FIG. 2. Epicycloidal Teeth.

two methods are identical as to the position of the resulting tooth-curve.

It afterwards occurred to me that the process would be in no way lengthened, or its difficulty increased, if the centres, found by the use of the table, were the centres of the circles which most nearly coincide with the true curves, instead of the Willis centres of the osculatory circles at the centres of the curves, and this is the method here given and illustrated by *Fig. 2* and the Table I.

The method adopted for the construction of the table was a mathematical process, tested by graphical processes. I first computed the co-ordinates of the points of the true curve at the adden-

dum point and at the centre of the curve, then the co-ordinates of the centres of the circles that pass through these two points and through the pitch points, and then the actual lengths of the radii of the circles as well as the distances of the centres of circles from the

GRANT'S ODONTOGRAPH TABLE I.—EPICYCLOIDAL TEETH.

INTERCHANGEABLE SERIES.

From a Pinion of Twelve Teeth to a Rack.

NUMBER OF TEETH IN THE GEAR.		FOR ONE DIAMETRAL PITCH. For any other pitch, divide by that pitch.				FOR ONE INCH CIRCULAR PITCH. For any other pitch, multiply by that pitch.			
		Faces.		Flanks.		Faces.		Flanks.	
Exact.	Intervals.	Rad.	Dia.	Rad.	Dia.	Rad.	Dia.	Rad.	Dia.
12	12	2.01	.06	∞	∞	.64	.02	∞	∞
13½	13–14	2.04	.07	15.10	9.43	.65	.02	4.80	3.00
15½	15–16	2.10	.09	7.86	3.46	.67	.03	2.50	1.10
17½	17–18	2.14	.11	6.13	2.20	.68	.04	1.95	.70
20	19–21	2.20	.13	5.12	1.57	.70	.04	1.63	.50
23	22–24	2.26	.15	4.50	1.13	.72	.05	1.43	.36
27	25–29	2.33	.16	4.10	.96	.74	.05	1.30	.29
33	30–36	2.40	.19	3.80	.72	.76	.06	1.20	.23
42	37–48	2 48	.22	3.52	.63	.79	.07	1.12	.20
58	49–72	2 60	.25	3 33	.54	.83	.08	1.06	.17
97	73–144	2.83	.28	3.14	.44	.90	.09	1.00	.14
290	145–rack.	2.92	.31	3.00	.38	.93	.10	.95	.12

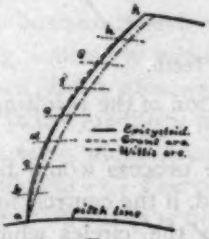

FIG. 3.

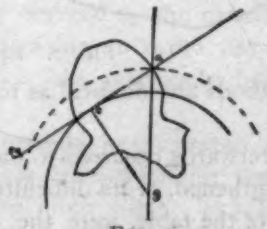

FIG. 4.

pitch lines. It is obvious that these circles are as close to the true curve as circular arcs can be made.

The improvement made in accuracy is illustrated in *Fig. 3*. The new arc crosses the curve twice, coinciding with it at three points, while the Willis arc leaves it at the pitch line and thence

runs entirely inside of it. The following table gives the errors of both arcs at nine points of a twelve-tooth pinion of a diametral pitch of unity, computed with great care to four places of decimals, or ten-thousandths of an inch. It is seen that the average error of the old curve is about six times that of the new.

	New Curve.	*Willis.*
At *a*	·0000	+·0000 inches.
" *b*	+·0088	+·0175 "
" *c*	+·0091	+·0244 "
" *d*	+·0056	+·0283 "
" *e*	·0000	+·0288 "
" *f*	—·0036	+·0297 "
" *g*	—·0061	+·0308 "
" *h*	—·0046	+·0342 "
" *k*	·0000	+·0397 "
Average	± ·0042	+ ·0260

The greatest error of the new arc is at about the quarter point *c*, and for a tooth of a diametral pitch of unity, twice the size of the tooth of *Fig. 2*, this maximum error is as follows:

For	12 teeth	*c* =	·009 inches.
"	20 "	*c* =	·008 "
"	40 "	*c* =	·006 "
"	100 "	*c* =	·004 "
"	300 "	*c* =	·002 "

The new curve is the most accurate, approximating most nearly to the true curve, at the point of the tooth, where accuracy is most needed, and where the Willis arc is most at fault.

Fig. 2 shows the two processes applied to a twelve-tooth pinion, the full arcs being by the new process and the dotted arcs by the Willis process. As the number of teeth increases, the accuracy of both arcs improves, until, for a very large gear either arc practically agrees with the true arc.

It may reasonably be claimed that the new arc is as near to the true curve as it is necessary to get, for hand and eye processes cannot appreciate a greater accuracy. It is doubtful if anything but the most delicately-constructed shaping engine could form a templet with a smaller error, for it is found in practice that templets constructed with the greatest skill by ordinary means, must be brought into shape by hand and eye processes, before they are

ready for use for the purpose of making gear cutters. The writer does not know of a purely mechanical process used in the construction of gear-teeth that will give closer results, except the Bilgram originating machine.

The Beale epicycloidal engine of the Brown & Sharpe Manufacturing Company will shape theoretically correct templets and templet gears with the greatest precision, the errors being all within a thousandth of an inch in magnitude, but, unlike the Bilgram machine, it has not as yet been applied directly to the shaping of the teeth of working wheels. But machines of this class can hardly

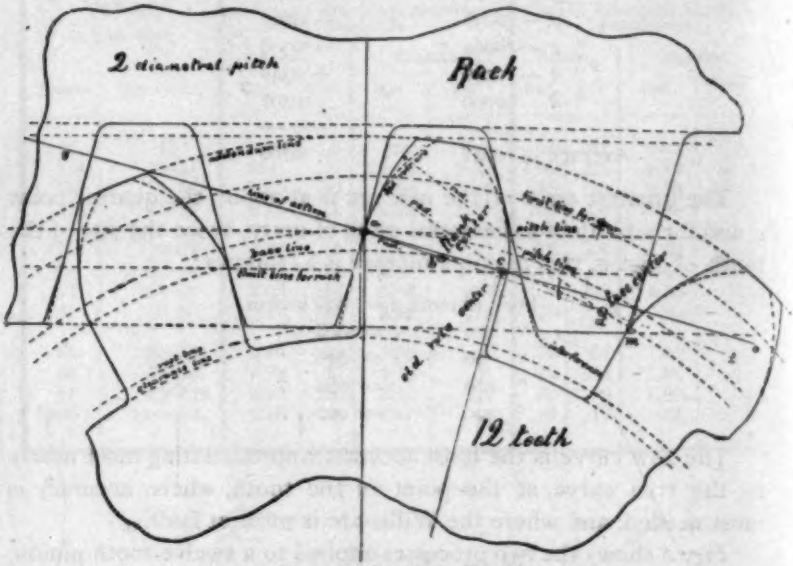

FIG. 5. Involute Teeth.

be compared with odontographs, as their expense puts them beyond reach for ordinary drafting or constructive purposes.

The principal application is to the interchangeable system of gear-teeth, but I have also applied it to the case, sometimes met with in practice, of teeth with radial flanks, not interchangeable. The upper number in each square of the Table II, is the face radius, while the lower is the centre distance. As shown by the table, most of the centres are inside the pitch line, some are on the line, while others, those having the negative sign, are outside of it.

A great advantage of the new method is that it can be applied

GRANT'S ODONTOGRAPH TABLE II.—EPICYCLOIDAL TEETH.

RADIAL FLANK TABLE.

FOR ANY POSSIBLE PAIR OF GEARS, NOT INTERCHANGEABLE.

One Inch Circular Pitch.

For any other pitch, multiply by that pitch.

NUMBER OF TEETH IN GEAR BEING DRAWN.		NUMBER OF TEETH IN THE MATE.											
Exact.	Intervals.	12	13 14	15 16	17 18	19 21	22 24	25 29	30 36	37 48	49 72	73 144	145 rack
12	12	.64 .02	.64 .01	.65 .01	.66 .01	.67 0	.68 0	.69 −.01	.70 −.01	.71 −.02	.73 −.02	.74 −.03	.75 −.03
13½	13-14	.65 .02	.66 .02	.67 .01	.68 .01	.69 .01	.70 0	.72 0	.74 −.01	.75 −.01	.76 −.02	.78 −.02	.79 −.03
15½	15-16	.67 .03	.68 .02	.69 .02	.70 .01	.72 .01	.74 .01	.75 0	.78 0	.79 −.01	.82 −.02	.84 −.02	.84 −.03
17½	17-18	.68 .04	.70 .03	.71 .02	.73 .02	.75 .01	.77 .01	.78 .01	.82 0	.84 −.01	.87 −.01	.89 −.02	.90 −.03
20	19-21	.70 .04	.72 .04	.74 .03	.76 .02	.79 .02	.81 .01	.83 .01	.87 0	.90 0	.93 −.01	.96 −.02	.96 −.03
23	22-24	.72 .05	.74 .04	.76 .04	.79 .03	.82 .02	.84 .02	.87 .01	.91 .01	.94 0	.98 −.01	1.01 −.02	1.03 −.03
27	25-29	.74 .05	.76 .05	.79 .04	.82 .04	.85 .03	.87 .02	.92 .02	.96 .01	.99 0	1.03 −.01	1.07 −.02	1.10 −.03
33	30-36	.76 .06	.79 .05	.83 .05	.86 .04	.90 .03	.94 .03	.98 .02	1.02 .01	1.06 0	1.11 0	1.17 −.01	1.23 −.02
42	37-48	.79 .07	.83 .06	.86 .05	.90 .05	.96 .04	.98 .04	1.03 .03	1.08 .03	1.14 .02	1.20 0	1.25 0	1.37 −.01
58	49-72	.83 .08	.87 .07	.91 .07	.96 .06	1.02 .06	1.05 .05	1.10 .04	1 17 .04	1.24 .03	1.30 .02	1.43 0	1.58 0
97	73-144	.90 .09	.93 .08	.97 .08	1.01 .07	1.07 .07	1.11 .06	1.18 .06	1.28 .05	1.34 .04	1.47 .03	1.65 .02	2.03 0
290	145 rack	99 .10	.96 .09	1.00 .09	1 05 .09	1.10 .08	1.16 .08	1.24 .07	1.37 .07	1 50 .06	1.70 .04	2.12 .03	2.90 .02

GRANT'S ODONTOGRAPH TABLE III.—INVOLUTE TEETH.

INTERCHANGEABLE SERIES.

From a Pinion of Twelve Teeth to a Rack.

NUMBER OF TEETH IN THE GEAR.		FOR ONE DIAMETRAL PITCH. For any other pitch, divide by that pitch.			FOR ONE INCH CIRCULAR PITCH. For any other pitch, multiply by that pitch.		
Exact.	Intervals.	Base Distance.	Face Radius.	Flank Radius.	Base Distance.	Face Radius.	Flank Radius.
12	12	.20	2.70	.83	.06	.86	.27
13	13	.22	2 87	.93	.07	.91	.30
14	14	.23	3.00	1.02	.07	.95	.33
15	15	.25	3.15	1.12	.08	1.00	.36
16	16	.27	3.29	1.22	.08	1.05	.40
17	17	.28	3.45	1.31	.09	1.09	.43
18	18	.30	3.59	1.41	.09	1.14	.46
19	19	.32	3 71	1.53	.10	1.18	.50
20	20	.33	3.86	1.62	.10	1.22	.53
21	21	.35	4.00	1.73	.11	1.27	.57
22	22	.37	4 14	1.83	.11	1.32	.60
23	23	.39	4.27	1.94	.12	1 36	.63
25	24- 26	.42	4.56	2.15	.13	1.45	.70
28	27- 29	.45	4.82	2.37	.14	1.54	.77
31	30- 32	.50	5.23	2.69	.15	1.67	.88
34	33- 36	.57	5.77	3.13	.17	1.84	1.00
38	37- 41	.63	6 30	3.58	.19	2.01	1.16
44	42- 48	.73	7.08	4.27	.22	2 26	1.38
52	49- 58	.87	8.13	5.20	.26	2.59	1.70
64	59- 72	1.07	9.68	6.64	.32	3.09	2.18
83	73- 96	1.39	12.11	8.93	.42	3.87	2.90
115	97-144	1.92	16.18	12 80	.58	5.16	4.15
192	145-288	3.20	25.86	22.30	.96	8.26	7.30
576	289-rack	9.60	73.95	70.10	2.88	23.65	22.30

INTERFERENCE

FOR TWELVE TO RACK INTERCHANGEABLE SET.

Teeth	12	13	15	17	19	22	25	30	37	49	73	145
In the gear.		14	16	18	21	24	29	36	48	72	144	∞
Pitch.	Amount of the Interference.											
One in. cir.	.003	.007	.007	.007	.007	.007	.010	.010	.010	.013	.017	.020
One diamet'l	.01	.02	.02	.02	.02	.02	.03	.03	.03	.04	.05	.06

Interference always to commence at a point half way between pitch line and addendum line.

to the involute form of tooth as well as to the cycloidal form. The involute is superior to the cycloid, theoretically and practically, but the Willis process does not apply to it, and if drawn at all, it is generally by the ridiculously inaccurate method shown by *Fig. 4*. By this simple, but worse than worthless method, the line *a c* is drawn at an angle of 75½° with the radial line, and then the tooth-curve is drawn from a centre, *c*, at a distance *a c* of one-quarter of the radius. Nothing could be simpler, and it would be difficult to contrive anything further from the truth, for the result on a twelve-toothed pinion is shown by the dotted lines of *Fig. 5*.

The new method, as applied to the involute, is given by the Table III, and illustrated by *Fig. 5*. The base circle is first drawn at the tabular distance from the pitch circle, and then the faces and flanks are drawn in with the tabular radii, from centres on the base circle. The supplementary table shows the necessary correction, for interference, on the points of the larger gears.

POPULAR ERRORS IN METEOROLOGY.

By Cleveland Abbe.

[*A Lecture delivered before the* Franklin Institute, *December 17, 1886.*]

The Lecturer was introduced by Dr. Wahl, Secretary of the Institute, and spoke as follows:

The pleasure with which I appear before you to-night for the purpose of directing your attention for a short time to some popular points in meteorology, is greatly increased by the recollection of those eminent scientists, who in this city and even in this hall, long since expounded some of the most important laws previously unknown, the knowledge of which has gradually worked a revolution in our views as to the philosophy of atmospheric processes.

You will remember that it was to Benjamin Franklin himself that we owe the general promulgation of the fact that many of our Northeast storms move slowly along our Atlantic Coast from Georgia to New England. It was here that he drew the lightning from the skies and wrested the sceptre from the hands of tyrants." To Godfrey, we owe the sextant, and to Rittenhouse the establishment of our first observatory with accurate methods of observation, both astronomical and meteorological. To Bache and the

Girard College, we owe the invention of several meteorological instruments, the establishment of our only extensive set of hourly meteorological records in America, and an elaborate discussion of the observations whence many interesting general laws were deduced; finally, to Espy, an active member of this Society, born in 1785, in Washington County, Pa., modern meteorology is indebted for such a thorough study of the clouds, of their methods of formation and of the secret of the growth of storms, whether the smallest thunder-storms, or the grandest hurricane, as has made him eminently worthy to receive the title "The Father of Modern Meteorology." Redfield gave us the statistics of storms, but Espy the philosophy of storms.

Fifty years ago the FRANKLIN INSTITUTE appointed a permanent Committee on Meteorology; to that committee we owe the study of meteors by Sears C. Walker, the establishment of a State Weather-Service for the especial study of thunder-storms, the discussions that helped to perfect Espy's theory of the formation of clouds and rain, the especial investigation of the New Brunswick tornado, the Meteorological Observatory of Girard College; and I should weary you were I to enumerate the many other steps in the progress of our science that I would place to the credit of the influence, direct or indirect, of that active committee. Gradually, however, its members were drawn to Washington—Henry, Bache, Walker, Espy—in succession, and at the Capital of the Nation they continued to agitate the importance of the study and the possibility of a practically useful weather-service. From 1842 until his death in 1860, Espy was untiring in his advocacy, in season and out of season, of the possibility of storm predictions and his four *Meteorological Reports*, as published by the National Government, constitute a lasting monument to his industry and enthusiasm. Whoever shall write a comprehensive life of Espy will sketch the progress of meteorology from its ancient to its present, and apparently even its future, condition. While speaking of historical matters affecting Philadelphia and the FRANKLIN INSTITUTE, let me add that the great State of Pennsylvania has also, through Prof. Coffin, of Easton, given us that great work *The Winds of the Globe*, and to crown all, has given us William Ferrel, who has been, not merely the great expounder and developer of Espy's views, but in all mechanical questions has been to meteorology

what Sir Isaac Newton was to astronomy. Espy, Redfield, Coffin, and Bache did what they could by experiment and observation and general reasoning without mathematical assistance, but William Ferrel (born June 29, 1817, in the southern part of Bedford County, Pa, and graduated at Mercersburg), published, two years after Espy's death, a treatise *On the Movements of the Atmosphere*, which has been followed by a series of important studies in the mechanics of the atmosphere, that has made his name recognized throughout the world as the leading theoretical meteorologist of the present age.

When now I speak thus decidedly of great changes in our views and great progress in our science, I imply at once that the older views have ceased to be accepted, and that a new order of things has arrived. We Americans are so accustomed to accept great changes in political, social, commercial, domestic and financial matters that we expect such also in scientific matters. We are sometimes tempted to speak of change as something synonymous with progress, but unfortunately this is not always the case, for errors are daily planted in men's minds only to be uprooted by the progress of the Creator's great law of survival and evolution, changes therefore become progress only when they are guided by a higher intelligence. Happily, however, in all the physical sciences, and especially in meteorology, we may speak certainly of undoubted progress during the past thirty years—progress that is known as yet mostly to the special students only, and has not yet made itself felt among the mass of people who have had no opportunity to keep up with this advance, and to whom, therefore, matters remain very much in the same state of belief in which they were in our childhood.

But every race, like every individual, has gone through its childhood, and many of the ideas prevalent among us a few years ago will be found repeated over and over again in the early poetry of every nation since the dawn of human history; much of the mythology of the Teutonic and the Latin races dates from an early period of which we know but little except what is handed down to us in the Sanscrit literature of Persia and Northern India. To those early ancestors of ours, the sun was the Ruler of Heaven; the little clouds, white and fleecy, were his sheep, of which the herds gathered in the morning from the West, were, during the day, driven

to the Eastern horizon, where they disappeared in the evening, and whence in some mysterious way they returned the next day from underneath the earth, to begin again their wanderings to and from their pasture-fields. But the bigger clouds, dropping little showers as they passed along, were his herds of cows dropping refreshing streams from their over-charged udders, while the great clouds black and threatening, whence thunder and lightning and wind were sent forth, were his own angry messengers sent to punish the wicked in this world, or the bad angels of the Spirit World fighting against the good. Such thoughts as these, which we now call poetry, expressed all that they then knew of meteorology, *and how much more did our own nurses and parents know*, who, on the approach of a summer thunder-storm, huddled us children together in a dark room on a feather bed and told us His angry eye flashed in the lightning, and His warning voice spoke in the thunder.

The student of science cannot possibly allow these beautiful or sublime phenomena to play thus upon his emotions; he recognizes the fact that whatever of the æsthetic there may be in Nature, and he himself is awake to it at the proper time, yet it must be temporarily ignored, while he is severely studying the underlying laws, by virtue of which the grand and the beautiful have their existence. So the sculptor masters the secrets of the ghastly skeleton before he can cover it with flesh and beauty. No one who beholds a beautiful spectacular play, wishes, in the midst of his enjoyment, to be reminded of the machinery behind the scenes; no one who is carried along by the orchestra cares to think of the laws of acoustics; no one in the midst of an elegant dinner enjoys a rehash of domestic and kitchen troubles—so, many dislike the student to spoil their enjoyment and turn their attention from Nature to Nature's laws; many even deem it sacrilege, if for a moment we omit to associate with the storm, the idea of God's power, or with the rainbow the promise of His Fatherly watchful care; many of you would even tremble for my orthodoxy if I should assert that neither revelation nor science authorizes a well-founded faith in the efficacy of prayers for rain, or against storms. What I said a few weeks ago about the earthquake applies equally to the weather: "We know perfectly well that an earthquake may occur at any time, and at any part of the world, and that our fancied security is simply the expression of our hope that one may not come here at

present. We must go on cultivating land and building houses because these things must be done, earthquake or no; the only effect that our knowledge of our liability to earthquakes should have upon us, should be, to make us seek to diminish their destructiveness, first, by a proper style of building, and, second, by such studies as will enable us to predict the time of their occurrence." Precisely so with storms and drought, frost and heat, we know these things must come upon the just and the unjust; what we have to do is to foresee them, predict and provide against them. Who would repeat the prayer in the old Russian prayer-book?

> "Lord, God, give pleasant sunshine,
> To us and to the Lobenstein,
> And if others want things good,
> Let them ask for it, to suit."

I hope, therefore, the time is now at hand when a popular error that has existed throughout the world for ages in regard to meteorology, shall be definitely and permanently dispelled, and we shall come to see clearly that the Creator never in the least interferes with the perfectly regular working of those laws concerning the atmosphere that were originally established by Him;—after He had finished the creation, *He saw that it was good*—and it has remained so to this day. And yet the fact remains that it is good to pray for whatever we need—it draws us nearer to God—just as a child will ask its parents, if it has anything of the spirit of love and affectionate dependence, but always with the provision: "Thy will, not mine, be done—thou knowest best."

Let us then recognize that in general the atmosphere is governed by immutable laws, and seek for the forces that control it. Almost anyone of us here, at the present time, would naturally say, the heat of the sun is the most important factor, and yet, strange as it is, there are millions who to-day are studying the moon and stars, or rather, they are basing their every-day lives upon weather predictions, published in the almanacs made up sometimes several years in advance by means of ancient astrological principles, whereas the plainest teachings of the real science of meteorology go to show that the influence of the moon, the planets and the stars upon our atmosphere is wholly inappreciable. It is vain to shut our eyes to the fact that Wiggins, Vennor, Capen, Foster and others in this country, and the Shepherd of Banbury,

in England, have a hold upon the credibility of the masses wholly unjustified by the value of their predictions, and are actually doing more harm financially than would cover the cost of all the Government Weather Bureaus in the World. One of the incidental benefits of our own Weather Bureau may be said to be its influence as an educator of the people; showing that every department of science can be made to contribute to man's comfort when systematically treated. Of all the heavenly bodies, except the sun, it may be safely said that the moon is most likely to have some slight influence on our atmosphere, but every effort to demonstrate such influence has so signally failed, that we may say with an astronomer of 100 years ago: "The moon *ought* to have an influence on the weather, but it *hasn't*."

We have, however, in those little dark spots that appear on the sun's surface a suggestion that has been worked up and overdone by very many; thus we have one who stoutly maintains that the appearance of any special "sun-spot" enables him to at once predict a corresponding special storm or weather. This idea has been arrived at apparently by a complete violation of all laws of logic. Areas of stormy or cold, or hot or windy weather, are so frequent all over the earth, and spots on the sun are so frequent, that it is always possible to pick out a number of coincidences in time; and the style of logic that demonstrates a certain storm to be caused by a certain spot would equally well be applied to demonstrate that my body is warmed by the mass of hot coals in the fire-place, while my cold hands are due to one special coal that will not burn as brisk as its neighbors.

The sun's spots vary appreciably; in a general way, our observations show it to be highly probable that the total amount of spottedness, or total frequency of spots on the sun, is accompanied by a slight change in the general condition of the earth's atmosphere, by reason of which, when fewer spots are visible on the sun, we have slightly *higher* temperatures on the earth's surface as a whole, but slightly *lower* temperatures in the equatorial regions. Again, for the maximum of sun-spots we have a slight minimum in the barometric pressure of the atmosphere; and again, for a maximum of sun-spots we have a slight maximum in the amount of rain-fall; and corresponding with this, at the time of the maximum of sun-spots, there is a little more water flowing

down the rivers of the world. Again, with the maximum of sun-spots there is a slight tendency toward a minimum of lightning and a minimum of hail-storms. But all of these relations are very feeble; that is to say, the changes in the condition of the sun's surface are very slight; they produce effects only barely appreciable in the earth's atmosphere as a whole, and it is utterly illogical to conclude that there is any direct connection between special spots on the sun and special localities on the earth. In fact, these studies simply confirm the conclusion that all our meteoric phenomena depend upon the sun's heat as such, and that any slight variation in this, by affecting the general atmospheric condition, may alter the rain in one part of the world, at the same moment that it alters the temperature in another place, or the wind in a third locality. May we, then, not hope that the sun-spots will gradually cease to appear (as they are now often made to do by sensational writers), as the cause of some special change in the weather, and be left in peace to work out quietly the slight influence they may have upon our atmosphere as a whole.

A singular belief has been handed down to us from remotest ages, to the effect that the animals, in their natural state, know more about the future weather than does man himself, and this idea has apparently grown out of the study of the habits of migratory birds and hybernating animals, all of whom do really seem to foresee the approaching seasons at least in a general way; it certainly has required the best power of the speculative naturalists to explain how such birds, for instance, as the wild duck, or the swan, ever came to think of making their long annual flights. We see the Indian go from the seashore, and a marine diet, in winter, to the forests and flesh diet in summer (or we see the modern American reverse this process), and we are not surprised, as we attribute it all to the intelligence of human beings, the necessities of their organization and the stress imposed by the changes in the season. Why, then, ought we to be surprised to find that the modern naturalist says that the migratory bird similarly inherits a gradually increasing amount of knowledge from his ancestors, that he has intelligence as well as the human being, and that he has not yet reached the limit of his intellectual development any more than has the white man? The migrations and the hybernating habits are, therefore, the result of the experience and teachings of many

past ages, beginning with the glacial epoch, and producing a habit of life in an intelligent animal to which he persistently adheres. It is not necessary to suppose that the Creator has given these animals a deeper knowledge of meteorology than has been given to human beings. He who consults the habits of the ground-hog, the crow, the spider, the wild geese, or the goose-bone, or the hundred other animals concerning which there are hundreds of rules in books of weather wisdom, is trusting to the intelligence of animals who are less intelligent than himself, and is neglecting to cultivate those faculties and habits of observation and reasoning with which his Creator has endowed him for the very purpose of getting at the mysteries of Nature and utilizing her powers to his own benefit. In other words, the meteorologist would say there is scarcely any truth in the idea that all these mute creatures have for self-preservation been fitted with what is to us an unknown sense, informing them of minute changes in the atmosphere long before the coming of the danger. They have either acquired their habits, as other intelligent creatures do, from experience and reason, or they are wholly guided by natural causes beyond their control.

The case of the Rocky Mountain Locust is an instance well calculated to illustrate this latter principle, *i. e.*, that natural causes sometimes direct every step. This "pest," after its last moulting, finds itself feeding in or near its native fields on the tender vegetation near the ground. Every day as the sun rises, after the dew is dissipated, it finds the atmosphere about it growing hot and dry and soon also its own moist tender wings become stiffened. There results on its part a nervous irritability which can be gratified best by active flapping of its wings, so that without any other profound instinct or intention on its part, it is carried upward above the ground to cooler, moister air, where strong northwest winds carry it rapidly southward, even to the Gulf of Mexico. Therefore, its migration into a region where rich pasture-lands await it, is not due to any superior knowledge on its own part. The eggs hatch out in these southern regions at a season of the year when strong southerly winds are more frequent, and thus the young locusts are by these carried back toward their starting place, without the intervention of instinct or inherited knowledge, but by causes beyond their control.

What is true of the animals is still more plainly true of vegetables, so that in fact nearly all the rules for weather prediction founded on the behavior of plants, such as the contracting of the down of the dandelion, the closing of the pink-eyed pimpernel, or of the convolvulus, in the day-time, or the gathering of dew on stones, or the falling of soot in the chimney, are all simply so many hygroscopic phenomena, and a well-made hygrometer, as used by meteorologists, will give more accurate indications than any of these natural objects.

Another erroneous idea, very widely prevalent, is shown by the tendency to explain this or that phenomenon as being due to atmospheric electricity or possibly to ozone. Both of these subjects have thus far eluded the attempt to observe them satisfactorily; we have, indeed, so-called records of electricity and ozone, but it is safe to say that with very few, if any exceptions, we have thus far been unable to interpret these records, and demonstrate that we have been really observing a purely atmospheric phenomenon, hence, I rate as a popular error, the frequent quotation of these as an active cause of meteorological phenomena.

We have many of us been accustomed to speak of the delightful influence of a summer thunder-storm in clearing and cooling the air, and it is true that cool clear air does frequently follow these storms. We are, however, here in danger of confusing cause and effect. A certain class of thunder-storms is not generally followed by cooler air; that is to say, any cooler than it would have been without the storm, while another large class is followed by a decided fall in temperature. In these latter cases, if I am not mistaken, the underflow of cooler air contributes so largely to the existence of the storm that at first sight one would say that the refreshing cooling of the air is the cause and not the effect. But a truer philosophy would show that uprising warm moist-air has caused both the inrush of cool air and the thunder-storm, so that the two latter do not stand to each other at all in the relation of cause and effect.

Many efforts have been made in this country to show that the destruction of our forests has affected our climate, and many instances are quoted to prove that the growth of forests on our treeless prairies has already materially modified the local climate—to neither of these views can I give my assent, and still less to the

theory advocated by some that the extension of telegraph and railroad lines has so affected the distribution of the electricity that more rain now falls in some localities than before. Of all such propositions, the weak point consists in the fact that we have not enough observations of rain-fall and temperature properly comparable with each other to justify any conclusion whatever. So variable is our climate, that a change of temperature of several degrees Fahrenheit, or a change of five per cent. in the average rain-fall could only be decided by comparing the average of 100 years of observation with the average of another 100 years taken before, or afterwards, under precisely similar circumstances. The mistakes in this respect have often arisen from an overweening confidence in one's memory. The oldest inhabitant confidently states that this is the coldest winter he ever knew; the leading newspaper reporter interviews him, and there appears a double-leaded article, with heavy head-lines: "Coldest Winter on Record. Decided Secular Changes in the Climate. Interesting Reminiscences of the Olden Time." The children and everybody read it, and become firmly convinced that the climate has changed, whereas the whole thing is based on the fallible memory of one man and the ready business-talent of another, and the truth is that, so far as our records go, whether of rain-fall, or temperature, or animal, or plant life, all things remain as they were in the days of our fathers; at least, so far as the atmosphere is concerned; a proviso that I insert because we are gradually getting proof of the occurrence of local changes of climate, consequent upon slow changes in elevation above sea-level.

If I have touched upon a few wide-spread popular misconceptions in regard to my science, I have still to take up a long list of questions frequently put to me and showing general, if not popular, errors widespread among this most intelligent nation; for instance, "Is the whirling-storm called hurricane, cyclone or tornado, caused by the friction between two great horizontal currents of air like the little whirls we see immediately behind a bridge pier in the middle of a river?" to which I answer, No! That was Dove's theory, but the meteorologists of to-day ascribe the tornado and cyclone to an uprush of air under one or more clouds, and the whirling is inevitable when the lower air rushes together from all sides to fill the place of that which has ascended. And here I

would call attention to an erroneous use of the word cyclone confined to some of the newspapers in this country, and which will, I hope, not be perpetuated, since many of the most reputable papers have already returned to a proper use of the word; the terms cyclone and hurricane should be applied to large storms only and the term tornado be restricted to those small and violent storms in which the up-draught through or around a central nearly vertical cloud or spout is the most prominent feature next after the terribly violent and destructive winds.

Again; among my questions is this:

"What is the special cause of the regular equinoctial storm?"

I am sorry to say that I know no "regular equinoctial." An old writer says, "Ye wind hath been noticed to be very tempestuous at ye time of ye equinoxes." All over the world it is a favorite habit among mankind to find a name, or a proverb, to suit every striking weather item: thus we we have a Sunday rain, a Michaelmas thaw, an equinox storm, a dog-day heat, etc. These names, however, are only names and prove nothing as to the reasons underlying the phenomena. With the changes of the sun's position and the consequent distribution of hot and cold air there come alike to old England and New England, months of stormy weather—the storm that appears next before or after the 21st of March, or the 21st of September, is dubbed the equinoctial of that year, but the name does not give the storm any other peculiarity. The frequency of storms is about the same for several successive weeks and one is as likely to occur on any other date as the date of the equinox.

Again; why is there less rain-fall caught in gauges high above the ground than in those on the ground. Do the drops grow as they descend?

The drops rarely grow after they have so nearly reached the ground, although they do grow as they descend through clouds of fog.

There is really the same amount of rain-fall at 100 or fifty feet altitude as on the ground; the fault is in our rain-gauge, which is exposed to stronger winds when set high up, and to almost no wind when flush with the ground. The stronger winds deflected around the gauge carry the drops to one side, and hence the higher gauge catches less than the lower one.

Among the experiments elucidating this principle are some made on your shot-tower, by Bache, fifty years ago, that have lately come to be more fully appreciated.

Again, why is it colder on a mountain-top near the sun?

It is a very common error to forget that everything—our own well-clothed bodies included—is giving out heat rapidly by radiation, and that the maintenance of any pleasant temperature is due to the fact that the loss by our own radiation is equalized by an equal gain through the absorption of the radiation from other substances. But this latter is wanting in the case of objects on the summits of mountains, which, therefore, cool rapidly and stay so.

Someone asks, "Why do all signs fail in dry weather?" and "Why are Signal Service predictions of rain specially erroneous during droughts?" There are probably several reasons for this, some meteorological, some subjective. During droughts, one generally sees clouds forming during the morning hours, as the ground becomes warmer and warmer, showing that there is moisture in the air, but that it is slightly less than needed to form rain. In this delicate balance between conditions favorable and unfavorable to rain, the predictor needs, but has not, observations of the conditions prevailing in the atmosphere at large, as well as those prevailing at the surface of the earth. The absence of the necessary knowledge, therefore, increases the chance of an erroneous prediction. There is, moreover, a slightly subjective or personal consideration, namely, being aware of the existence of the drought and the great desire for rain, he is liable to yield to the desire we all feel to say something pleasant, or to predict that which will be most agreeable if it occurs; thus, the hope that it may rain, colors his predictions, so that between the two phrases, "fair weather" and "fair weather, possibly followed by light local rains," he is likely to adopt the latter as his prediction. The farmer who receives the latter sees the clouds gathering, and when the local thunder-storm passes by leaving him dry, but wetting some distant region, in his disappointment he calls the whole a failure; whereas the occurrence of even that slight local rain in a limited region has been for the Signal Service predictor a complete verification, but the clamor of the thousands who did not receive the rain, overpowers the quiet rejoicing of the hundreds who did receive it.

Finally, it may be considered as a popular error that the people should *expect* the Army Signal Office to make perfectly correct local weather predictions thirty-six hours in advance for their benefit. That this is expected, we know by the grumbles we hear when a failure is announced. There even seems to be a growing disposition to look to the Signal Office for general weather or climatic predictions several weeks in advance of the season. Such predictions have been made in a few other countries, but when we consider the special methods that have been invented for that purpose, you will realize how very unsatisfactory such predictions may become. Thus, suppose we have for Philadelphia 100 years of daily weather records, and find that January 1st has during these 100 years been rainy ten times, snowy twenty times, fair—namely, neither rain nor snow—seventy times, then we should naturally predict for next New Year's Day fair weather, as the chances are in favor of that. But, after all, the favorable probability is too slight to be of much value. In the present state of our knowledge, these predictions will probably not be verified one-fourth of the time, and a person will do just as well to regulate his business without them. This latter conclusion I have heard sometimes made in a carping way with reference even to the well-known daily weather indications of the Signal Office; but this, I am sure, is altogether too sweeping, and nothing could be more erroneous than to condemn the great work of that office because of an occasional, or even a frequent failure, since by general consent, and by actual numerical data made up from the returns of hundreds of independent observers throughout the country, we know that those who from day to day regulate their business by its predictions find great profit therein.

However, I am by no means sure that detailed long range weather predictions would be very agreeable or profitable—"sufficient unto the day is the evil thereof." What would you do, my hearer, if you knew exactly what the weather is to be hour by hour for this next coming year. Would you be able to pick out the best day on which to plough, or sew, or reap? On *this* day the prediction gives you fair weather; will you plant at once, knowing that the prediction says heavy frosts on *this* day three weeks later, just in time to kill your young crops? Will you reap to-day because the predicted weather is highly favorable, knowing

that before half of that crop can be gathered into your barns the predicted hail-storm will be upon you? As nearly as I can see, he who should perfectly foreknow the weather would find himself at every step confronted by some approaching dilemma, some inevitable disappointment or loss; and shrinking, as we all do, from such events, he would sit down in despair and do nothing at all. In a general way, it is true of the weather, as of anything else, that an All-Merciful Father hides the future from us so that we, in our ignorance and helplessness, may labor on, full of hope that things may not turn out so bad after all.

And yet, so confident am I of the great future development of man and of science, and so clearly do I see the wise provision by which *everywhere in Nature we find the right thing, in the right place, at the right time*, that I dare predict to-night *the time will come* when men shall be able to endure and utilize detailed weather predictions for months and years in advance; and when that time comes the prophet and his predictions will be on hand.

THERMODYNAMICS.

By Professor De Volson Wood.

During the past year, the writer published several articles upon Thermodynamics in Van Nostrand's *Engineering Magazine*, which were designed chiefly to explain some parts of Rankine's treatment as given in his work, on *The Steam Engine and Other Prime Movers*. These articles were somewhat discursive, due to the circumstances under which they were written, and, since the publication of that magazine has been discontinued, I now seek the pages of this Journal for the purpose of considering a few points more critically. The writings of eminent scholars show that the more abstruse parts of Rankine's thermodynamics are not easily understood, and in our own experience we have found his treatment in his *Steam Engine* more difficult than in his original papers. This is particularly the case in regard to his "second law," which Maxwell considered as "inscrutable," and other writers, even down to the present time, have considered it necessary to attempt an explanation of what Rankine really meant.* His *Steam*

* At least as late as 1885. Address before the Mechanical Section of the A. A. A. S., at Ann Arbor, Mich., *Science*, September, p. 212.

Engine being used as a text-book, the meaning ought not to remain ambiguous, nor be left in the condition described by a writer of repute when he states: "While Rankine, if referred to at all, only his very words are quoted, showing that their scope is not fully grasped." * It is possible that sufficient explanations exist in published works, but if so, we are ignorant of the fact, and for this reason contribute the result of our study in attempting to determine his essential meaning—the very scope of his words, hoping that the points which remain obscure may quickly be removed by others. We select for the beginning of our study the paragraph which we consider the most difficult, being Article 241 of the *Steam Engine*, which, for the convenience of the reader, we quote, as follows:

"THE SECOND LAW OF THERMODYNAMICS.—*If the total actual heat of a homogeneous and uniformly hot substance be conceived to be divided into any number of equal parts, the effects of these parts in causing work to be performed are equal.* * * * The symbolical expression of the second law of thermodynamics is as follows: Let unity of weight of a homogeneous substance, possessing the actual heat Q, undergo any indefinitely small change, so as to produce the indefinitely small amount of work dU. It is required to find how much of this work is performed by the disappearance of heat. Conceive Q to be divided into an indefinite number of indefinitely small parts each of which is δQ. Each of those parts will cause to be performed the quantity of work represented by

$$\delta Q \frac{d}{dQ} dU,$$

consequently the quantity of work performed by the disappearance of heat will be

$$Q \cdot \frac{d}{dQ} dU, \qquad (1)$$

which quantity is known when Q, and the law of variation of dU with Q, are known."

We find, upon investigating this quotation, that no mention is made of certain essential principles, without which *the analysis cannot be established.*

* Van Nostrand's *Engineering Magazine*, 1879, p. 337.

Since the symbolic expression is a representation of the law, it may be used in explaining that law; and the law—if understood—may be used in explaining the analysis. The author, in speaking of the change, says: "Let the substance undergo any indefinitely small change;" from which one might infer that the change was arbitrary, but we will show that expression (1) is correctly produced only when the change is made according to a definite law—which law is *that of constant actual heat in the substance while doing work*. This is vital, and hence should, for the benefit of the student, have been mentioned. In a text-book, the student naturally expects to find the statement of principles preceding the analysis upon which the latter is founded; or, at least, in close proximity thereto, but in this case he will find the principle just referred to several pages in advance, near the latter part of Article 245, where it says, "It is to be observed, that the function U, representing the work performed by the kind of change under contemplation, is first to be investigated as if the temperature were constant." Work is performed by this substance only by enlarging the containing vessel, so that if v be the volume, the elementary charge will be $d\,v$; but "the change under contemplation" referred to in the preceding quotation, may include a change in temperature and pressure as well as of volume, in which case, it must be observed that the function is *first* to be investigated as if the temperature (or actual heat) were constant.

The uninitiated may suppose that $\delta\,Q$ is necessarily different from $d\,Q$, but such is not the fact, as is shown by Rankine's use of it in his original papers, where the expression is written:

$$d\,Q\frac{d\,P}{d\,Q}d\,V,$$

which is equivalent to

$$d\,Q\,\frac{d\,(d\,U)}{d\,Q}.$$

Moreover, as will appear in the sequel, if $\delta\,Q$ be different from $d\,Q$, then $\delta\,Q$ cannot properly be written as it is without making a partial solution of the problem, and is nearly equivalent to a complete solution of that part of it; for the operation by which Q is obtained in expression (1) is the same as that by which $\delta\,Q$ would be obtained from $d\,Q$, still assuming that they are different, but if

different, it is certainly correct to reduce δQ to that of dQ, so that the expression

$$dQ\frac{d}{dQ}dU$$

will be correct if the former is. The mathematical operation of deducing expression (1) from this consists of an integration, thus

$$\int dQ\frac{d(dU)}{dQ}=Q.\frac{d^2U}{dQ} \qquad (2)$$

but this is correct only when $\frac{d^2U}{dQ}$ is independent of Q. This fact is vital in the operations of the calculus, but we will illustrate it by a special case. Let it be proposed to find the area of a curve referred to polar co-ordinates. Proceeding as above, we conceive the area to be divided into indefinitely small parts, each equal dA. Conceive the angular space to be divided into an indefinite number of small parts, each $d\theta$, then will the area of one part be

$$d\theta\frac{dA}{d\theta},$$

and hence for the angular space θ, the area would be

$$B=\theta.\frac{dA}{d\theta},$$

in which the last operation is equivalent to integrating the former expression considering $\frac{dA}{d\theta}$ as independent of θ. Now, this result is correct when $\frac{dA}{d\theta}$ is independent of θ; or, more generally, when it is constant. It is not generally true. For instance, the general expression for dA is

$$dA=\tfrac{1}{2}\rho^2d\theta,$$

which, substituted above, gives

$$B=\theta.\tfrac{1}{2}\rho^2=\tfrac{1}{2}\rho^2\theta$$

which is the area of the sector of a circle whose angle is θ, but for no other curve. The process, therefore, by which the value of B was found, is not general; it is correct for the circle, because $\frac{dA}{d\theta}$ is independent of θ.

If the angular space be divided into indefinitely small parts by circular arcs, then we would have

$$B = \int\int d\theta \frac{d^2 A}{d\theta} = \theta \int \frac{d^2 A}{d\theta}.$$

But

$$d^2 A = \rho \, d\theta \, d\rho;$$
$$\therefore B = \theta \int \rho \, d\rho = \tfrac{1}{2} \rho^2 \theta;$$

as before, when $\frac{d^2 A}{d\theta}$ is independent of θ, as it is in the case of the circle.

In order to show more definitely the signification of $d^2 U$, let p be the pressure upon the inside of a vessel containing the expanding substance, and dv the amount of increase of the volume; then if v be an independent variable, p, being dependent upon v, we have

$$dU = p \, dv;$$
$$\therefore d^2 U = dp \, dv$$

and expression (1) becomes

$$Q \cdot \frac{dp}{dQ} \, dv. \tag{3}$$

Still further, it is more convenient to speak of temperature than of actual heat. Actual heat, or total actual heat, is simply the heat energy which remains as heat; it is called *sensible heat.* It is not the heat absorbed by a body. Thus, in changing water to steam, a large amount of heat is absorbed which is not sensible, being 966 thermal units for one pound of steam generated, the temperature remaining constantly at 212° F. Q does not include latent heat. The sensible heat from the supposed condition of total privation of heat, varies directly as the absolute temperature from the same zero. Equal quantities of *sensible* heat in a fixed weight of a substance, correspond to equal measurements on a scale of temperature, so that we have

$$Q : Q' :: \tau : \tau',$$

or

$$Q : dQ :: \tau : d\tau,$$

and expression (3) becomes

$$\tau \frac{dp}{d\tau} \, dv \tag{4}$$

The pressure is some function of the actual heat, or

$$p = f(Q)$$

and hence

$$\frac{d\,p}{d\,Q} = f'(Q)$$

may contain Q; or

$$\frac{d\,p}{d\,\tau} = f'(\tau)$$

may contain τ. To illustrate, it does not contain τ for the perfect gases, for then we have the well-known relation,

$$p\,v = R\,\tau;$$

$$\therefore \frac{d\,p}{d\,\tau} = \frac{R}{v} \qquad (5)$$

considering v as constant. But for imperfect gases, accepting the form given by Rankine and Regnault, we have

$$p\,v = R\,\tau - \frac{a}{v} - \frac{a_1}{v\,\tau} - \frac{a_2}{v\,\tau^2} - etc.;$$

$$\therefore \frac{d\,p}{d\,\tau} = \frac{R}{v} + \frac{a_1}{v^2\,\tau^2} + \frac{2\,a_2}{v^2\,\tau^3} + etc. \qquad (6)$$

which is a function of τ. Since the analysis is not restricted to perfect gases, but, as the sequel shows, includes imperfect ones, we see that

$$\frac{d^2\,U}{d\,Q} = \frac{d\,p}{d\,\tau} d\,v = f'(Q) = f''(\tau),$$

is a function of Q or τ. How, then, can expression (1) be obtained from that just preceding it? Or, what is the same thing, how can the reduction in equation (2) be correct? It cannot, unless $f'(Q)$ can be maintained constant during the expansion. This can be done by supplying heat to the substance from an external source; and this is what is actually done, or conceived to be done, during this operation. If a gas expands, doing work without heat being supplied to it, the temperature will fall; or, if compressed, under similar conditions, the temperature will rise; but by supplying heat, the temperature may be maintained constant, and, when so maintained, the expansion is called isothermal. If the base of a cylinder be perfectly pervious to the passage of heat, and in contact with an indefinitely large source of heat at the actual heat Q, or temperature τ, then may the temperature of the substance be maintained constantly at that heat while the pis-

ton moves out any finite distance, say from v_1 to v_2. Whatever be the means of maintaining the constant heat, the fact of a constant temperature must be conceived of in this part of the analysis, even when the expansion is indefinitely small. This is also a vital condition in the solution. We observe, then, that having written the identity

$$d\,p\;d\,v = d\,\tau\,\frac{d\,p}{d\,\tau}\,d\,v, \qquad (6)$$

the latter expression is not permitted to be reduced to the former by the cancellation of $d\,\tau$, but a part of it, viz., $\frac{d\,p}{d\,\tau}$, is taken by itself and treated independently of the other terms of the expression before an integration is performed, its value being formed directly from the equation of the gas as shown above; or, as one may conceive, found by a direct experiment upon the substance, by finding the increase of the pressure $d\,p$ due to a very small change of the temperature $d\,\tau$, at some volume v. It is apparent that there is a great advantage in using the equation of the gas, when known, for it not only enables one to find directly the value of $\frac{d\,p}{d\,\tau}$, but also retains the value of v, so that the law of change dependent upon the volume, to be considered in a following operation, is retained in a form ready for use. The value of $\frac{d\,p}{d\,\tau}$ is a function of v, both for perfect and imperfect fluids, as shown in equations (5) and (6), but this fact does not prevent the integration of (2) in regard to Q or τ, for by the principles of the calculus, an integration may be performed in reference to one of the variables as if the other were constant. The expression $\frac{d\,p}{d\,\tau}$, or $\frac{d^2\,u}{d\,Q}$, is a partial differential, being a value in which all the variables of the function are constant except p and τ; or, as there are only three variables in this case (p, v, τ), it is a differential coefficient, found on the condition that v is considered constant, although in reference to $d\,v$ it will be considered variable in a later operation. The partial differential is sometimes indicated by a parenthesis, thus, $\left(\frac{d\,p}{d\,\tau}\right)$, and some writers upon this subject introduce a subscript to show which variable is considered as constant; thus,

when v is considered constant, it may be written $\left(\frac{dp}{d\tau}\right)_v$. Clausius proposed to indicate this operation by placing the v as a subscript to d, thus, $\frac{d_v p}{d\tau}$, and Baynes writes the partial differential with a special symbol. Rankine says nothing about these forms, but when he distinguishes a total differential from the partial, writes the latter in the usual form, and places a period after d for the former. Thus, the total differential is written $d.H$, $\frac{d.\varphi}{d\tau}$, etc., as on pp. 310, 316, 320 of *Steam Engine*, the description of which appears to be contained in the words "represent respectively the *complete rates of variation*," near the middle of page 316. This is another instance in which the author has used a notation, not of the customary form, without any intimation of its significance until six pages after its first use. We also note in passing, that it is omitted in some places where its use is of vital importance, as in the expression $\tau\, d\, F$, page 310, which should be written $\tau\, d.F$ to conform with his own notation; since F is a function of τ and v, as shown by his analysis, and which is actually written in full in one of his original papers, thus:

$$d.F = \frac{dF}{d\tau}\, d\tau + \frac{dF}{dv}\, dv$$

While these omissions and tardy explanations may cause no difficulty to one versed in the science, they cannot fail to be vexatious to the student while acquiring this knowledge, and were it not for the fact that the author was a deep thinker, a strong writer and generally accurate in his processes and results (though there are exceptions) it would not pay to follow him; but, as it is, there is often a great satisfaction in studying his methods.

Returning now to the fundamental expression, which, for reasons already given, we write—

$$dQ\frac{d^2U}{dQ} = dQ\frac{dp}{dQ}dv = d\tau\frac{dp}{d\tau}dv,$$

and making $\frac{d^2U}{dQ}$, or $\frac{dp}{d\tau}$, independent of Q, or τ, by making Q in the former and τ in the latter constant during the expansion of

the substance by supplying heat from an external source, the expression may be integrated once in reference to Q or τ, as the case may be, between limits. If dW be the work, both external and internal, done by one pound of the substance due to the heat dQ in expanding from v_1 to v_2 at the heat Q, then

$$d^2W = \frac{dp}{dQ}\,dv\,.\,dQ = \frac{dp}{d\tau}\,dv\,.\,d\tau \qquad (8)$$

$$dW = \int_{v_1}^{v_2} \frac{dp}{d\tau}\,dv\,.\,d\tau \qquad (9)$$

$$\int_{W_2}^{W_1} dW = W_1 - W_2 = \int_{\tau_2}^{\tau_1}\int_{v_1}^{v_2} \frac{dp}{d\tau}\,dv\,d\tau = (\tau_1 - \tau_2)\int_{v_1}^{v_2} \frac{dp}{d\tau}\,dv, \qquad (10)$$

and the last term can be integrated when the equation of the gas is known, τ being treated as constant. Thus, for a perfect gas we have

$$pv = R\tau;$$

$$\therefore \frac{dp}{d\tau} = \frac{R}{v};$$

$$\therefore \int_{v_1}^{v_2} \frac{dp}{d\tau}\,dv = \int_{v_1}^{v_2} R\,\frac{dv}{v} = R\,log\,\frac{v_2}{v_1};$$

$$\therefore W_1 - W_2 = (\tau_1 - \tau_2)\,R\,log\,\frac{v_2}{v_1}.$$

A part of this analysis will be recognized as that of the elementary heat engine, and, although the analysis is simple, questions may be raised in regard to the physical conditions which it is not advisable to consider at this time.

Students ask—how can $\frac{dp}{d\tau}$ have a finite value, as in equations (5) and (6), when τ is constant?" It may be considered that $\frac{dp}{d\tau}$ is the rate of change of pressure per unit of temperature when the temperature is τ as in equation (6), and its value found when τ is variable; but having found the general value, τ may be maintained constant during expansion by a supply of heat, as already explained.

The last clause of the quotation from the text is, "Which quantity is known when the law of variation of dU with Q are known." This expression implies a relation between an infinitesimal dU and a finite quantity Q, which, mathematically speaking, is zero. The law of variation actually referred to, is between p and Q, or p and τ, the latter being used in practice, and should have been so expressed.

Another expression in the extract is: "It is required to find how much of this work is performed by the disappearance of heat." This is a difficult sentence to explain. The work referred to is $p\,dv$. The fact is, *all* of this work is supposed to be done by the disappearance of heat; and, as the sequel shows, more than this amount of work is done. This work, $p\,dv$, is entirely external work, like work done by a moving piston, but at the same time work of a molecular character is done, like the work of changing water to steam, or ice to water. The latter are extreme examples, but serve as striking examples of the character of internal work. In the case of ice, the internal work of fusion is thousands of times the external work, and the latter is negative; and in changing water to steam at 212° F. at one atmosphere the internal work is more than eleven times the external. There is always internal work in expanding an imperfect gas isothermally, but none in expanding a perfect gas. In the case of perfect gases, all "of this work is performed by the disappearance of heat;" and in the case of imperfect gases, not only all, but more "work is performed by the disappearance of heat." The implication of the author is that only a part of the work $p\,dv$ is performed by the disappearance of heat; but it is impossible for this to be generally true. We say *generally*, because if our statements above are generally correct there might be *exceptions* which would make the wording of the author correct, just as in algebra a quantity considered positive may prove to be negative. We assume that the author did not intend to use exceptional cases in establishing a general proposition, and are therefore forced to the conclusion that the sentence is logically defective—that it does not fully express the idea of the author—and hence we must seek for the idea in the context, or elsewhere in his writings, or from the essential principles of the subject. We observe, first, that if the words "of this" be expunged the reading will agree with other passages

of the text. Thus, just before expression (1) it reads, "the quantity of work performed by the disappearance of heat will be," which would be an answer to the demand above if the words "of this" were expunged. Three or four lines above the same idea is expressed, and again, on page 310 of the *Steam Engine*, it is repeated thus: "Then the work performed by the disappearance of heat is," and, as the sequel shows, all of these expressions include not only the external work, but internal also. By consulting his original memoir on the subject (*Miscellaneous Scientific Papers*, page 311), we find that the same language is used—"How much of this work is the effect of heat?"—but the analysis which follows shows that he considered that the work done by the disappearance of heat *exceeded* the external work, for he writes—

$$\left(Q\frac{d\,p}{d\,Q}-p\right)d\,v$$

for the molecular potential energy caused by the disappearance of heat.

It has been suggested that Rankine may have supposed that some other agent than heat, as electricity, magnetism, external or internal stress, or some unknown agent, was involved in doing the work $p\,d\,v$, but we do not find this view confirmed by his statements, nor by succeeding analysis, neither do we see how the effect of these agents can be separated by his process. If other agents than heat are working, changing the actual heat (or temperature) a small amount might change the energy of the other agents as well as the heat agents, unless, indeed, the action of the other agents are independent of heat, in which case there would be as little occasion for including them in the discussion as it would be to mention the fact of the moon's attraction upon the piston of the engine. It appears then that, so far as the text and context are concerned, no violence will be done to the author, or to the sense, if the words "of this" are cancelled—and they may, with propriety, be omitted. Still, we cannot satisfy ourself that the author used them inadvertently, or that the particular meaning which he wished to convey would be expressed without them. Even if not used inadvertently, the article bears evidence, as we have already seen, of having been hastily written; some of the essential ideas involved in the analysis not being mentioned; so that in this

case we assume that these words may be suggestive of some idea not yet assigned, the expression for which must be sought from a knowledge of the subject. Considering it in this light, we infer that it may mean—how much less work would be performed by the disappearance of an element of heat from the substance. A part of the work $p\,dv$ was done on account of the last element dQ of heat added to the substance, so that the idea is—how much of this work is due to an element dQ of the heat of the substance. But work destroys heat—causes an equal amount to disappear—so again we may say, how much of this work is performed by the disappearance of an element of heat from the substance. If the total actual heat of the substance be Q, it will, by an isothermal expansion, do the external work $p\,dv$; but when the actual heat of the substance is $Q - dQ$, it will do only a part of $p\,dv$ when

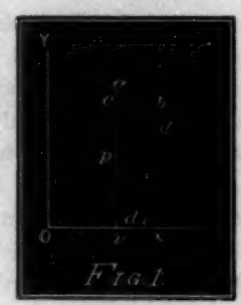

Fig. 1.

expanding isothermally—how much of it? Although the following analysis supports these interpretations of the sentence; yet it should be noticed that the expression "disappearance of heat" is not generally used in this sense. It generally refers—not to an element of heat permanently abstracted from the substance, but to the heat disappearing in doing work. Let $o\,v$, *Fig.* 1, represent the volume of one pound of the substance, $v\,a = p$ the corresponding pressure, and $a\,b$ the isothermal at the temperature τ. Let the expansion be $d\,v$ at the constant temperature τ, then will the external work done be

$$v\,a\,b\,x = p\,dv.$$

Let another isothermal $c\,d$ be drawn, representing a temperature $\tau - d\,\tau$, then would the external work be $v\,x\,d\,c$, and the difference between $v\,a\,b\,x$ and $v\,x\,d\,c$, or $a\,b\,d\,c$ represents the work done on account of the substance possessing the heat dQ above what it had

when it did the work $v\,x\,d\,e$; that is above $Q-dQ$. Or, to put it another way, it represents the loss of work due to the permanent abstraction of the temperature $d\,\tau$ from the substance during a given expansion. We have

$$c\,a\,b\,d = d\,p\,d\,v,$$

but p is a function of τ directly when v is constant, which fact, according to the notation of the calculus, may be indicated thus,

$$c\,a\,b\,d = \frac{d\,p}{d\,\tau}\,d\,\tau \cdot d\,v;$$

which, as an algebraic expression is equivalent to the preceding, and so appears at once by cancelling $d\,\tau$. But, if we now proceed as before, to operate upon $\frac{d\,p}{d\,\tau}$ by itself, we will find the rate at which the pressure increases per unit of absolute temperature. It is at this point that the analysis gets hold, so to speak, of the internal work, a fact which is the most difficult to realize, and the most difficult to explain in this whole analysis. *The heat absorbed while work is being done at isothermal expansion, must equal the entire work done*, and of this work all that is not external must be internal. It is the determination of the internal work which makes the problem difficult—since it cannot be measured directly, and can be determined only through the other measurable quantities of the problem. If the quantity of heat absorbed could be directly measured, we would thus, at once, determine the total work done, but this can be determined only by means of external work. The total heat absorbed under isothermal expansion can be determined by a method which we think is explicit and easily understood, and may be given later in this discussion; but at present we desire to follow, as closely as possible, the process of the author.

Admitting that internal work was done while the external work was $v\,a\,b\,x$, it will be apparent that some other element of internal work was done when the external work was $v\,c\,d\,x$, so that a slight change in the temperature of the substance not only affects the external work, but the internal also, and the latter is some function of the former. Admitting that the *rate of change* of the pressure per unit of temperature, when the pressure is p and temperature is τ, is determined by decreasing the temperature of the substance $d\,\tau$, and observing the corresponding diminution of pressure $d\,p$ at

the constant volume v, it will appear that this ratio is different for different gases, and that $d\,p$ will be greater for more imperfect gases for the same diminution of temperature. This being an abstruse point, we illustrate it by equation (6), which is

$$\frac{d\,p}{d\,\tau} = \frac{R}{v} + \frac{a_1}{v^2\,\tau^2} + \frac{2a_2}{v^3\,\tau^3} + etc.$$

in which the ratio $\frac{d\,p}{d\,\tau}$ is greater, the greater the values of a_1, a_2, etc., and is least for a_1, a_2, etc., equal zero, the latter giving

$$\frac{d\,p}{d\,\tau} = \frac{R}{v} = \frac{p}{\tau},$$

the value for perfect gases. The last ratio, $\frac{p}{\tau}$, shows that for perfect gases the ratio of the increment $d\,p$ to $d\,\tau$ varies directly as the total pressure to the absolute temperature.

(*To be continued.*)

The MEIGS ELEVATED RAILROAD.

(*Report of* George Stark, C. E., *to the Board of Railroad Commissioners of the State of Massachusetts.*)

To the Board of Railroad Commissioners of the State of Massachusetts.

Gentlemen:—I had the honor to receive from you, on the 27th of October last, an appointment "as engineer under the provisions of Section 4, Chapter 87, of the Acts of 1884, for the purpose of examining the safety and strength of the structure of the Meigs Elevated Railway, so-called, in Cambridge, and the rolling-stock and motive-power used thereon, and of approving or disapproving the same." In pursuance of this appointment, I have since devoted a very considerable portion of my time and attention to the required examination, and beg leave now to submit this, my report:

The experimental section of Meigs elevated railway, which has been constructed at East Cambridge, is located on grounds formerly occupied by the Bay State Glass Company, and extends over Bridge Street to grounds of J. P. Squire & Co.

The structure has been erected wholly on made land, upon what was once the bed of Miller's River, and the mud underneath this made land is soft and deep. A rod of round iron, five-eighths of an inch in diameter, was easily forced down, near the structure, by one man, in my presence, its entire length, twelve feet, without striking hard bottom. The difficulty of building a secure single-post structure on this foundation has, of course, been much greater than it would have been on ordinary solid land. In addition to this natural difficulty, Captain Meigs has purposely introduced artificial obstacles in his track, for the purpose of showing that he can run his trains around curves of less radius and on grades of greater elevation than are now practicable on ordinary steam motor railways, and can safely pass horizontal or vertical angles in the track, of very considerable deflection. One of his curves makes an entire semi-circle, with a fifty-foot radius, on a grade of 120 feet to the mile, and another turns nearly a quarter circle with a radius of fifty feet, on a grade of 345 feet to the mile.

The construction of the track is simple, and the question of its strength and safety is easily determined. The entire structure consists of a single line of girders supported on a single line of posts; the two rails on which the bearing-wheels supporting the load run, being placed on the upper outside corners of the lower boom of the girder, and the two rails that resist the pressure of the horizontal driving- and guiding-wheels being placed on the other sides of the upper boom of the girder.

The problems to be solved are: (1) as to the strength of girder for sustaining a vertical load, represented by the fixed weight of the girder and the moving weight of the train passing over it, and for resisting the horizontal strains and twists that may come either from the grip of the driving-wheels or the momentum of the train, or the action of wind; and, (2), as to the strength of the posts, for sustaining the weight of girders and trains, and their stability and power of resistance against side-pressure, caused by momentum or wind blowing upon the side of the train.

The railway company has submitted to my examination extensive and thorough computations, made by engineers in their employ, to show the force of these various strains, and the amount and form and quality of material required in the girders and posts to safely resist and bear the loads and strains to which they are,

or may be, subjected. These computations show that the structure as built is, theoretically, of ample strength and stiffness, under all circumstances, to safely carry the train; and the numerous trips that I have myself made over it with the locomotive and cars, practically verify these theoretical calculations.

But for the purpose of more tangible verification, I caused one of the longer girders to be loaded, in my presence, with a known weight of nearly double the amount that could be brought upon it by the train, and noted myself the results, by gauges arranged to show the deflection. The girder experimented upon is about forty-six feet long, and its lower boom is about eighteen feet above the surface of the ground. Two large iron cylinders (rendering tanks) laid on cross timbers, were suspended under the exact middle of the girder by means of a heavy chain passing over the upper boom. The tanks were then filled with water, making an aggregate weight of water, tanks, chain and timber, of 60,187 pounds, or about thirty net tons, equal to a distributed weight of sixty tons upon the girder—a load greatly in excess of any that could ever be put upon it by the train. The depression of the girder at its centre under this load was seven-sixteenths of an inch, and, on removing the load, the girder sprang back to its original position.

To test, practically, the power of the girder to resist lateral strains arising from pressure of wind and unbalanced loads, computations have been made, based upon the force of a hurricane blowing 110 miles an hour squarely against the side of the train, when the load is out of balance by passengers being at the same time all on the leeward side of the car. The side-pressure on a girder, arising from these extreme conditions, is computed to be equal to about $4\frac{42}{100}$ tons. By means of a cable, attached to the centre of a girder, and passing horizontally over a loose pulley in the top of a shear, and suspending vertically a platform loaded with pig-iron, I applied a force of $5\frac{29}{100}$ tons, to pull the girder sideways, being an excess of twenty per cent. over the computed extreme force of combined hurricane and unbalanced load. The side-deflection of the girder at its middle caused by this pressure of $5\frac{29}{100}$ tons was three-eighths of an inch. This pressure caused the posts supporting the girder under test to bend at their tops one-half of an inch. On removing the weight, the girder and posts sprang back to their original position.

As the iron posts are of good design and well-built, and securely fixed in place by foundations of timber and concrete, and have stood the pressure and strain of the train passing over them at frequent intervals for some months, I consider them satisfactory, and that no further test of their strength is necessary. The method of filling them with concrete, so arranged as to mainly take the weight, instead of leaving it to be supported by the iron shell, is especially commendable.

The wooden posts, now in use on the low part of the structure, answer very well for experimental purposes, but in a line intended for city traffic, I should advise that iron posts filled with concrete be adopted in all cases.

The structure of this experimental piece of railway, as now submitted to my examination, is, in my opinion, safe, and sufficiently strong, except in the plate-angle iron rails on the lower boom of the girder, which have proved too light, and are about to be replaced with heavier ones. It contains, however, objectionable curves and grades and angles, purposely placed there for extreme tests, to show what obstacles may be overcome if necessity compels them to be encountered, and to find out what changes may be desirable in the proportions of the machinery. In my opinion, these extreme features should be eliminated, and, wherever possible, kept out from any line intended for business purposes.

The motive-power and rolling-stock submitted to my examination, consisted of a locomotive weighing about thirty tons, a tender weighing about fourteen tons, and a passenger car weighing about seventeen tons, making up a train of about sixty-one tons, aggregate weight, when empty.

Excepting the distinctive running gear, or trucks, of this railway system, the general features of the motive-power and rolling-stock correspond to, or are supposed improvements upon, the locomotives and cars of ordinary steam railways.

A cylindrical shape has been adopted for all the equipment; for which shape peculiar advantages are claimed as to safety, convenience and economy, and particularly as to offering less resistant surface to the wind.

The car is more elegant and commodious internally than ordinary cars, and, being largely built of metal instead of wood, is

safer as regards fire, or as regards splinters, in case of accident. The turn-table arrangement of the trucks also seems stronger and safer than the trucks now in common use.

The leading features of the system centre in the trucks. They are constructed to straddle the girder, so that, if all the bearing wheels were knocked off, the fall of the truck would not be over two or three inches, or to the top boom of the girder, on which it would slide or rest.

The wheels that bear the weight instead of being placed in the ordinary upright position, are fixed at an angle of about 45° from the vertical plane. The bearing face of the wheels is grooved to fit down upon the angle-iron supporting rail, on the upper corners of the lower boom of the track girder, so as to bear both downward and inward on the rail. Each wheel has its own independent axle, securely fixed in the iron jaw of the truck, at right angles to the plane of the wheel. By this arrangement, the axle strains and the slipping of wheels on curves, so troublesome in axles of the ordinary construction, are wholly avoided; and it becomes possible to use sharper curves in the track than have ever before been practicable. Each truck has also two horizontal guide-wheels, bearing against the rails on the sides of the upper boom of the track girder, to prevent the truck from swaying.

As the sustaining rails of the track on the lower boom of the girder are but twenty-two and one-half inches gauge, and the wheels stand sloping outward from these rails, on an angle of about 45°, the first appearance of the rolling-stock to a casual observer, is one of extreme instability. But upon investigation and practical test, this appearance is found to be deceptive. Careful mathematical and mechanical analysis of the arrangement of the wheels and axles shows the plan to be theoretically correct; and that, as a matter of fact, this arrangement of trucks, upon properly constructed girders, is more stable and safer, than the trucks of ordinary rolling-stock upon the ordinary railroad tracks.

For the purpose of testing the safety of these trucks in the event of accident, I caused one wheel to be removed from a truck under the car, so that the car would be in the condition of losing a wheel by breakage while in motion. The train was then run over the track with one wheel gone. There was no perceptible tipping of the truck on account of the absence of this wheel, and

no apparent tendency to derailment. The absence of the wheel would not be noticeable to passengers in the car.

I also caused a section of the supporting rail and timber of one side of a lower boom to be cut away and removed, leaving an open gap of about six feet in the track. The car was then pushed over this gap, and, of course, became derailed; but it only dropped about two inches, and slid along on the upper boom as securely as if on its wheels. The centre of gravity being but little above the boom on which the car rested, the side wheels and track jaws held the car effectually in horizontal position, with very little strain. Apparently, a derailed car, on this system, could not tip over, which cannot be said of ordinary railroad cars on the ordinary railroad tracks.

The locomotive has some minor novelties of construction beside the truck arrangement above alluded to, not necessary here to describe; but its main features are the horizontal driving-wheels which pull the train by side pressure on the rails of the upper boom of the girder, and the hydraulic attachment by which the pressure of adhesion of these driving-wheels upon the rails is created, maintained and regulated, at will, by the engine-driver.

This motor has accomplished some remarkable feats. It draws itself and the attached train, with apparent ease, and great speed, around sharper curves and up heavier grades, than the ordinary locomotive can pass. But, being the first of the kind ever built, of full size, and having been from the outset put at work on a track purposely planned to bring out in this experimental stage any existing weakness of design (through trial on unusual grades and curves and angles, requiring machinery of great perfection and power to overcome these extraordinary obstacles), it has, as might be expected, proved weak in some of its minor proportions, and there has been more or less breakage in the strained parts. All the defects thus far developed seem, however, to be susceptible of easy remedy, and no doubt, in future construction, the proportions of the parts will be greatly improved.

With so radical a departure from the ordinary mode of applying locomotive-power, it is only to be expected that perfect proportions will develop slowly, and out of the results of extended use, or practical experiments. This is but the usual rule, applying to all inventions.

The result of my investigations may be summed up as follows:

The experimental section of the Meigs elevated railway now in use at East Cambridge is, in my opinion, abundantly strong for its intended use as an elevated railway track, and is safe for the passage of its equipment.

The rolling-stock and motive-power used thereon are also strong and safe for their intended use, no breakage having occurred, or being likely to occur, that could imperil personal safety, either in or out of the cars.

A line of railway, properly constructed on this principle, for passenger or freight traffic, and equipped with such rolling-stock and motive-power, on this principle, as the Meigs Company is now prepared to perfect and build, would, in my opinion, be, at least, as strong and safe for any kind of traffic as the ordinary surface or elevated steam railways now in common use.

In view, however, of the imperative necessity for the best class of design and construction in everything appertaining to an elevated railway, I think it would be wise for the state of Massachusetts, through its board of railroad commissioners, or otherwise, to regulate the strength and design of all materials used in construction, and the weight and design of equipment to be run, etc., as is done by New York, through its "rapid-transit commission," for elevated railroads in that state.

I attach to this report some sketches, kindly furnished by Capt. Meigs, showing a perspective and a sectional view of his track and equipment, and the methods used by me for applying the weight and pressure tests to the girders and posts.

Respectfully, your obedient servant,

GEORGE STARK, *Civil Engineer.*

Boston, December 23, 1886.

ANNUAL REVIEW OF INDUSTRIAL PROGRESS.

[*From the Report of the Secretary, read at the Annual Meeting, January 19, 1887.*]

THE YEAR 1886 was characterized by the continuance of the favorable conditions which were well-defined towards the close of the year which immediately preceded it, and, in spite of the serious check to commercial and industrial activity, caused by the prolonged and widespread labor troubles, it was a notably prosperous year, and witnessed a substantial and very general revival of our industries.

The industrial revival was reflected in the most satisfactory manner in the iron trade, in respect to which the year 1886 was the most prosperous ever known in the history of these industries in the United States. Though it is too early to give the figures of production with strict accuracy, the estimates which have just been published by Mr. Swank, the Manager of the American Iron and Steel Association, and from which I abstract the more important data, will afford a sufficiently close approximation to answer my purpose in this review.

In his annual summary of the iron trade, which appears under the significant caption, "A Prosperous Year," Mr. Swank remarks, that the improvement which commenced in 1885 was continued, with but slight interruption, throughout the year, which was one of great activity. He gives us the following facts and figures: Our production, in 1886, of pig iron, Bessemer steel and steel-rails, open-hearth steel, structural iron and steel, and some other products, has been much larger than in 1885, and our production of pig iron, Bessemer steel, Bessemer steel rails, and open-hearth steel has been much the largest in our history. He estimates the production, in gross tons, of these four leading products in 1886, compared with the production in 1885, to have been as follows:

Products.	—*1885.*— *Gross Tons.*	—*1886.*— *Gross Tons.*
Pig Iron,	4,044,526	5,600,000
Bessemer steel ingots,	1,519,430	2,000,000
Bessemer steel rails,	959,471	1,500,000
Open-hearth steel,	133,375	200,000

He adds, "the figures for 1886 have been estimated with care, and we believe will be fully verified by the official returns, which we are now collecting from the manufacturers. They are marvellous in their mere magnitude, but more marvellous still in showing our progress as iron and steel producers in one year. Our production of iron ore in 1886 was about 10,000,000 tons, and we imported about 1,000,000 tons. During 1886, this country built over 7,000 miles of new railroad, against 3,131 miles reported by Mr. Poor for 1885. This great increase in railroad building in 1886 contributed largely to the improvement in our iron and steel industries."

It is worthy of special note, in this relation, that during the past year

the United States outstripped Great Britain as a producer of at least one important product—namely, Bessemer steel, and that, assuming the same ratio of increase to be maintained, at the close of the present year, we will have also taken the lead as producers of pig iron. These comparisons, apart from their interest, are instructive, since they exhibit perhaps more strikingly than any other form of illustration, the rapid growth of this country, both in respect to its productive capacity and its consumption.

The domestic production of coal has kept pace with the increased production of iron and steel, and the increased activity of our domestic manufactures, and the production for the year 1886, though as yet it is too early to obtain correct figures, will undoubtedly be found to be larger than that of any previous year in our history.

In Constructive Engineering, I have no remarkable advances to record. The more interesting items that seem noteworthy are the following:

The subject of enlarging the facilities of the Suez canal, to which reference was made in my report for last year, may be considered as definitely settled. The commission of engineers, which was appointed, in 1884, to decide upon the most feasible measures to be undertaken to enable the ship canal to meet fully the exigencies of a traffic exceeding 10,000,000 tons per annum, after a full consideration of the three methods proposed for increasing its carrying capacity —namely: (1), widening the existing canal; (2), constructing a second canal; and (3), doubling the capacity of the canal by a combination of the first two methods—has decided unanimously in favor of the enlargement of the existing canal from the Mediterranean to the Red Sea. The principal reasons assigned for this decision, were, that it would permit vessels to increase their speed through the canal from five and one-third to eight knots per hour, thus shortening the time of passage to twelve hours; that there would be only two banks to maintain instead of four; that the danger of collision between passing vessels would be lessened; and that it would enable each successive portion of enlargement to be at once utilized as an addition to the passing places for vessels. The estimated cost of this enlargement is placed at about $40,000,000.

Statements and opinions concerning the actual condition and prospects of the Panama canal are as conflicting as ever. The projectors of the enterprise appear to have succeeded in obtaining a considerable addition to their funds, independent of the Government aid which was asked for, and during the past year the work of excavation has been considerably advanced. They speak as positively as ever of the completion of the canal, and announce that it will certainly be opened for traffic in the year 1889. On the other hand, it does not appear that those portions of the work, which have excited the gravest apprehensions respecting their feasibility, have thus far been touched; charges of gross mismanagement, and extravagant expenditure of money, have been freely made; and prediction of the total collapse of the enterprise has been ventured by the most eminent financial authority in France. Whatever view one may take of the ultimate fate of the enterprise at the hands of

its projectors and present managers, it is now admitted, that the canal will cost a vastly greater sum than they imagined it would, and that they greatly underestimated the difficulties of their undertaking.

Mr. Geo. W. Plympton, discussing the much-debated project of flooding the Sahara, disposes of the exaggerated notions entertained of the extent of the area which would thus be flooded, by showing that the united areas of the several "chottes" over which the sea would flow, is about 3,100 square miles, or less than half the area of Lake Ontario.

The Eads's ship-railway project is still discussed, and though its advocates were not successful last year in inducing Congress to act favorably on their proposition that the United States should join with Mexico in guaranteeing to make good a certain amount of income for a series of years, it is not improbable that a further effort in this direction may have better success, or, that the work may be assumed by private enterprise.

The work upon the new Croton aqueduct, which was referred to in my last yearly summary, has been considerably advanced, but will still require several years for its completion.

It may be of interest to note, in this place, that the subject of improving the condition of the water supplies has attracted more attention during the past year from the authorities of American cities than ever before. The city of Chicago is engaged in perfecting plans for an improved and more abundant supply, and in Philadelphia, the results of a very thorough survey, undertaken to determine the best source for its future supply, have just been published.

IN THE FIELD OF ELECTRICITY, while the year of 1886 was not distinguished by any notable discovery, substantial advances were made in many of its practical applications. I shall take note of those only, which appear to be the most important.

In *telegraphy*, the ingenious system of Mr. Lucius J. Phelps, of transmitting messages to and from railway trains in motion, by utilizing the principle of induction, which received the distinction of an award of the Scott Legacy Premium and Medal, on the recommendation of this INSTITUTE, and which was noticed in my summary of the previous year, has been improved in its practical details. It has lately been placed in operation on the Lehigh Valley Railroad, and, I am informed, is shortly to be introduced on the main line of the New York, New Haven and Hartford Railroad. A system, having the same object in view (that is, transmitting messages to and from moving railway trains), but employing static induction, was proposed during the past year by Mr. Edison, and was widely talked-of in the technical journals. From all that I can learn of this system, certain practical difficulties have been encountered in its operation, which have not yet been overcome, but, for an inventor of such fertility of resources as Mr. Edison, these difficulties are not likely to prove insurmountable.

In fac-simile *telegraphy*, an ingenious system of transmitting diagrams,

charts, sketches, etc., has been proposed by two English officers, Lieutenant-Colonel Melville and Lieutenant Glen, which promises to prove a useful acquisition for military purposes. It consists, substantially, in dividing a blank sheet into a number of blocks or squares, each of which shall be designated by a number or letter, on a pre-arranged scheme. By telegraphing a series of these numbers or letters, a series of dots will be obtained, which, when joined so as to make continuous lines, will form the desired outline or tracing.

In *multiplex telegraphy* there is nothing of importance to record. In *submarine telegraphy*, the adoption by the Mackey-Bennett lines of the Muirhead system of duplicating may be noted as a substantial advance. The *Electrical World* notes, as an advance in *land telegraphy*, the duplexing of lines by the use of the condenser, which has made it possible to employ the telephone as a receiver supplementary to the ordinary telegraph relay. This plan also is the invention of Mr. Edison, and is called the "phonoplex." It renders it practicable to work duplex to any intermediate station on a line, which was not possible by the old duplex system. The system has found its practical application in railroad telegraphy, where many stations are, as a rule, included in the same line.

In *telephony*, some progress has been made in the establishment of long-distance lines. A number of lines were in practical operation between New York and Boston during the past year, and the results were so satisfactory that a number of lines have been constructed between New York and Philadelphia. The system employed is said to be that of Mr. Gilliland, in which a continuous metallic circuit is used. It is probable that the present year may witness the considerable extension of long-distance telephony.

In connection with this branch of the subject, the suggestive experiments of Messrs. Bell and Taintor, in reproducing spoken words by means of "sensitive jets," are worthy of note; as, likewise, are the experiments of Professor Dolbear in establishing telegraphic communication without the use of a metallic conductor, and which gives promise of success.

The past year witnessed the continued extension of *electric lighting*, both for public and domestic uses. Improvements in great number have been announced, but none appear to be of a radical character. Considerable discussion has been called forth on account of the alleged advantages of the Gaulard & Gibbs system of employing alternating high-tension currents, and converting these, by means of an induction-apparatus, into low-tension currents suitable for incandescent-lighting. By this system of distribution, a great saving of copper for conductors is claimed to be effected, and the cost of service greatly diminished. The practical value of this system still remains to be demonstrated. It is stated that preparations are being made by the Westinghouse Company to introduce it upon an extensive scale, in connection with a scheme of introducing fuel-gas, in which the existing gas-light companies will be invited to participate.

The subject of *electric transmission* received its full share of attention. The use of electric motors has considerably increased, and electric-lighting companies, finding it profitable to rent out their current during the day-time

when it is not required for lighting, are systematically encouraging its use. The *Electrical World* reports that the number of electric motors of all kinds in use in the United States exceeds 5,000, and that this number is increasing very rapidly. The same authority speaks hopefully of the *electric-railway*, of which it predicts that it "will be nothing less than revolutionary in its effect upon inter-urban transit."

In the construction of *primary* and *storage batteries*, the record of the past year reveals no improvements of a radical nature

The *electric-smelting* process of the Cowles Brothers, which this INSTITUTE has crowned with its highest honors, has continued to justify the favorable opinions which all thoughtful observers have entertained respecting its capabilities. During the past year an electric-smelting plant, on a greatly-enlarged scale, has been erected and put in operation at Lockport, N. Y., and is at present running at its full capacity. The only commercial products turned out thus far are the aluminium bronzes, for which, at the reduced cost at which it has been found possible to manufacture them in the electric furnace, there appears to be a large and constantly growing demand.

An invention of much interest in this field is the process of *electric welding*, which was brought out last year by Prof. Elihu Thomson, an honored member of this INSTITUTE. By this process it is said to be possible, not only to effect the welding of pieces of metal which cannot otherwise be welded, but also to weld pieces of different metals. The invention, it is affirmed, is capable of general application.

Finally, I will notice, in taking leave of this theme, that the subject of *underground wires* in cities has received more general attention and discussion during the past year than ever before, and, that in a number of places, notably in New York, Brooklyn, Philadelphia, Boston and Chicago, substantial progress towards the practical solution of this troublesome problem was realized.

IN CHEMICAL TECHNOLOGY, the procedure proposed by Mr. H. Y. Castner for the production of the metals of the alkalies, by which, it is claimed, the cost of these important products will be considerably reduced, appears to be worthy of notice. Mr. Castner's improvements relate principally to the employment of a metallic carbide (in the form of a carbide of iron) to effect the reduction, which he claims to be able to accomplish at comparatively moderate temperatures, with the charge in a state of fusion, and claims, further, to obtain practically the entire yield of metal contained in the charge. By the process used down to this time, the temperatures required are very high; the wrought-iron retorts employed are speedily burnt out; only small charges at a time can be operated with, and the yield is not much above thirty-three per cent. Mr. Castner's claims are now being subjected to the test of a practical examination, and if they are substantiated, the invention will prove valuable, as the cheap production of sodium will affect many branches of the chemical and metallurgical arts.

REVIEWING THE PROGRESS of the great industries of mining and metallurgy, the *Engineering and Mining Journal* gives the following interesting summary, which indicates for these industries a remarkable degree of progress, technical and commercial:

"Never before in this country was the number of paying mines so great, or its proportion to the whole number worked so large. And never before were the improvements in metallurgy so interesting or their results of greater practical importance. The cost of production of every metal has been reduced.

"In mining, the wonderful skill evolved from intelligent experience with machine-drills, and the introduction of cheap high explosives, have brought our ordinary every-day work to a point in speed and economy that a few years ago would have been considered as improbable as the telephone. Coal-cutting machinery and mechanical underground haulage are effecting a notable economy in the cost of producing that most important of all mineral products—coal.

"The twenty-ton copper-furnace has given place to the simple little water-jacketed shaft that smelts from 100 to 150 tons a day at an expenditure of about as many cents as it formerly cost dollars; the successful application of the Bessemer method to the treatment of copper ores; a vast increase in the capacity and economy of lead furnaces; the reduction in the cost of the treatment of zinc ores, which has brought this metal down to, and even below, the price of lead; improvements in the production of sulphuric acid that have made half a cent a pound for commercial acid a profitable price, even where the pyrites used have come from distant Spain; improvements in the crushing, concentration, roasting, amalgamation and chlorination of gold and silver ores; in the bromination of gold ores; in the electrical separation of metals; in furnaces and machinery used in the production and manufacture of iron and steel, which have made possible the wonderful records of our iron and steel works; excellence in design and construction of bridges; of locomotives, and machinery of all kinds, which have demonstrated to the outer world their superior economy and efficiency, compared with old-world types; the cheaper production of electricity and its general application for power, light and heat; progress in the practical utilization of waste products. These and many more are subjects in which our American engineers have made, and are making, records that challenge the attention and admiration of the world."

IN MAY, 1885, Mr. Nordenfelt exhibited at the meeting of the British Iron and Steel Institute some remarkable specimens of castings made by the direct melting of wrought iron, which at once attracted attention, Much curiosity was manifested to learn by what process such results, heretofore only obtainable by the method of forging, had been obtained. Since then the details of the process have been given to the public, and the past year has witnessed the practical introduction of the "*mitis*" process of producing wrought-iron and steel castings in Europe and in this country. The process depends upon the addition, to the raw material employed, of an exceedingly small percentage of another metal, which has the effect of

causing an immediate and considerable lowering of the melting-point of the wrought iron used in the operation. This remarkable effect is produced by the addition, to the charge of wrought iron heated just to the point of fusion, of from 0·05 to 0·1 of one per cent. of aluminium, in the form of an alloy of iron and aluminium. By this addition, an immediate lowering of the melting point of the charge is produced, and the charge at once becomes thinly fluid; and, being superheated to the extent of perhaps 500° F., it may readily be handled and poured into castings before chilling sets in. For the practical working of the process, a number of special improvements in the form of the heating furnaces employed, in the mode of casting, etc., have been devised, and the process appears to be practically successful. It has lately been introduced into the United States. In this relation, the following brief quotation from the comments on this process, which I made at a recent stated meeting of this INSTITUTE, and which were published in the JOURNAL several months ago, may not be out of place.

"The simplicity of this process, the certainty with which it can be operated, the uniformity of the product, and its admirable qualities in respect to strength and ductility, indicate an extended field of usefulness for it. The most difficult forms have been successfully produced in mitis castings, such as pulleys, smoke-consumers, wheels, knees, bends of piping, etc., having the tensile-strength of mild steel forgings, at but slightly greater expense than for castings of ordinary shape; and it is claimed, with good reason, that there is scarcely any form of forging which it would not be more advantageous to cast by this method. The mitis castings threaten to seriously incommode the manufacturers of malleable castings, for which they not only offer a perfect substitute, but one which, in respect to strength and ductility, is distinctly superior; while for many purposes, mitis castings can be employed for which malleable castings could not be made. The mitis process has also been applied to the production of steel castings, and with very promising results."

It is of interest to record the fact that the element *fluorine*, which has hitherto obstinately resisted all efforts to isolate it, has at last been obtained in its elemental state, by a French chemist, M. Moissan, who, with great difficulty and with the aid of most ingeniously-contrived apparatus, succeeded in separating it from its combination with hydrogen by the electrolytic method.

Fahlberg's *saccharine*, though not a recent discovery, attracted some attention during the past year. The discoverer has been busily engaged in improving its manufacture with the view of cheapening the cost of production, which, by the latest published statements, has been brought to about $12.50 per pound. Though this appears very high, it is not prohibitive of its use as an addition to glucose, since its sweetening power is so great. The experiments that have been made with it seem to indicate that it is quite harmless, and that in addition to its extraordinary sweetness (which is estimated to be 230 times greater than that of cane sugar) it possesses decided antiseptic powers. It may soon find practical application as an addition to glucose for the various uses to which this substance is put.

In last year's summary, I noted, at some length, the remarkable revolu-

tion in industrial and domestic economy, which the general introduction of *gaseous fuel* had brought about in the cities and towns situated within the natural gas belt. During the past year, the growth of the gas producing industry, and the substitution of the new fuel for the old, have continued at so rapid a rate, that the most enthusiastic advocates of the change are amazed at its extent.

Passing by the use of gaseous fuel for domestic purposes, as of secondary importance, there can be no doubt of the fact that the adoption of natural gas for fuel by the iron, steel and glass manufacturers of Pittsburgh and its neighborhood has given so great an advantage to these industries in that favored region, that competing manufacturers elsewhere, in many instances, have found themselves compelled to remove their establishments to some point within the gas region, and many others are considering the expediency of following this example at the first opportunity.

While the immediate results of the circumstances here referred to, must be to give a great impetus to manufactures of all kinds in the cities and towns lying within this favored region, it is scarcely conceivable that they will be permitted to enjoy exclusive advantages indefinitely; for, with the knowl- that there are means available for the artificial production of fuel gas at a cost sufficiently low to compare favorably with the prices at which natural gas can be supplied, the manufacturers in every industrial centre throughout the country, sooner or later, will be compelled, in self-defence to adopt this expedient.

Far-sighted men are already discussing the feasibility of converting the existing coal-gas works in our cities and towns into fuel-gas works, thus utilizing the existing mains and distributing pipes, and, by the simultaneous introduction of the incandescent system of electric lighting, effect at once a two-fold revolution.

THE PAST YEAR will be memorable in the annals of the country for the destruction of a large portion of the city of Charleston, S. C., on the 31st of August, by an earthquake, the effects of which were felt over an area of 900,000 square miles. The immediate vicinity of Charleston appears to have been the centre from which the disturbances emanated, and the destruction of property in that city was enormous. The only offset to this great calamity, is the fact that, destructive as it was to property, comparatively few lives were destroyed.

REPORTS OF THE COMMITTEE ON SCIENCE AND THE ARTS.

[No. 1348.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 31, 1886.

The Sub-Committee of the Committee on Science and the Arts, to which was referred the products of the Celluloid Manufacturing Company, of Newark, N. J., presents the following report:

The very fine display, which the Celluloid Manufacturing Company, of Newark, N. J., made at the late "Novelties" Exhibition of the FRANKLIN INSTITUTE, led the judges of the group under which they were classified to recommend the award to them of a silver medal, and to call the attention of the Committee on Science and the Arts to the very meritorious character of their exhibit.

Sub-Committee No. 1348, to which the matter was referred, has examined the claims, as presented at that time, and has considered additional statements made by the company as to their recent efforts to find new avenues of useful employment for this material, and one of the committee has visited the factory of the company, at Newark, and has seen their manufacturing processes in detail.

The committee believes that in celluloid has been found a very valuable substitute for ivory, a natural product growing scarcer every succeeding year. Many articles, formerly made from ivory, like piano-keys, billiard-balls, handles for cutlery, etc., are now made, not only cheaper, but better, from celluloid, the perfect uniformity in appearance of which, and its density and freedom from tendency to crack make it in every way superior to ivory. Similarly, for amber and vulcanite, celluloid makes a very desirable substitute. Especially for the latter, has it been advantageously substituted in the manufacture of plates for artificial teeth, in which the amount of pigment, necessary to give them the color of the natural gum, is only a small fraction of that necessary for vulcanite. Moreover, celluloid is entirely free from sulphur, a necessary ingredient of vulcanite.

The company showed, moreover, in their exhibit, that celluloid was admirably adapted for a great variety of uses, and that in each case it had positive advantages over the material it replaced.

One of the most important applications of celluloid, which the company have been busily pushing since the time of the exhibition, is its use in the manufacture of stereotype plates for print-

ing. Here it replaces, with numerous advantages, too, the heavy and expensive metal castings. These celluloid stereotype plates are light, tough and elastic, and can readily be sent through the mails. They take ink freely, give excellent impressions, and can be easily cleaned and dried. With the aid of these celluloid stereotype plates, the news associations of the large cities are able to supply the newspapers of interior places with matter ready for printing at very low prices.

The Sub-Committee, recognizing the part the Celluloid Manufacturing Company has had in developing the possibilities of this new material, by their expenditure of labor and capital in pushing the invention of the Hyatt Brothers, and their continual work in experimenting with reference to new applications of celluloid, would recommend the award to the company of the ELLIOT CRESSON GOLD MEDAL, *for the introduction of a new raw material of great possible value, and for its successful utilization in many important industries.*

W. C. HEAD, SAM'L P. SADTLER, *Chm.*,
H C. SELLERS, WM. H. WAHL.

Adopted December 1, 1886.

H. R. HEYL, *Chm, Committee on Science and the Arts.*

[No. 1358.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, August 30, 1886.

The Sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE of the State of Pennsylvania, to whom was referred for examination the

AIR-BRUSH

of the Air-Brush Manufacturing Company of Rockford, Ill., respectfully

Report: That after an examination of the instrument and its uses, they regard it as deserving of the warmest commendation. The application of the principle of the air-brush to a tool for distributing liquid pigments on to paper or other surfaces in the production of pictures, is a great novelty in the arts, and as important in its economy of time as it is novel. In the hands of an accomplished draughtsman, it is an acquisition of rare value.

Of course, this instrument cannot make up for any deficiency of

artistic skill in the operator, for, as much proficiency in drawing practice is necessary with this as with any other of the pencils or brushes heretofore used. What is chiefly claimed for it by its inventor is, that it facilitates his work by shortening greatly the time consumed in the execution, and that it is more durable than crayon or pastel when used in imitation of those styles. Artistic displays of freedom of touch can readily be added over the finished work of the air-brush by those who prefer to do so, and still the work will appear homogeneous in method of execution when the same pigments are used in both cases.

One of its merits, is that tints laid on by means of the air-brush possess the advantage of appearing equally well whether the light falls on them from one side or the other. This is not the case with tints made with the crayon, as is well known, for the reason that the toothed surface of the paper gets more completely covered on the side towards the light than it does on the shaded side, consequently, a drawing that appears smoothly finished in the light in which it was drawn, is apt to look rough and coarse when viewed with the light falling on it from the opposite direction. The reason of the difference is obvious—the air-brush throws the color directly down into the pores of the paper, covering equally both sides of the projecting tooth of the surface, so that naturally the work looks well in whatever light it is shown.

The manner in which the air-brush delivers the color to the paper may be described in few words, thus: the artist supplies liquid color from a brush to a spoon-like reservoir. Through this liquid a fine needle darts rapidly back and forth, its wetted point being carried forward beyond the edge of the spoon A strong current of air blown against this needle's point carries off the small amount of color adhering to it in finely divided particles, thin and fine at the point of departure, but widening out as its distance increases. Hence, if the instrument is held near the paper, it will make fine lines, when moved as in writing, but removed to a distance, it will make broad, soft tints with gentle blendings. The greater or less length of stroke of the needle, as well as the current of compressed air playing on it, is all the time completely under the control of the artist by action of his thumb while working, the supply of air to the chamber being pumped in by action of his foot.

We have only to add that this remarkable invention is an

important aid to the artist, and we believe it deserves the highest award that the FRANKLIN INSTITUTE has in its power to bestow.

JOHN SARTAIN, *Chm.*,
JOHN CARBUTT,

November 3, 1886.

Amended to incorporate the award of the ELLIOT CRESSON MEDAL, and as so amended adopted. H. R. HEYL, *Chairmen.*

[No. 1306.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 28, 1886.

The Sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE of the State of Pennsylvania, to whom was referred, for examination,

THADDEUS S. C. LOWE'S INVENTIONS AND IMPROVEMENTS IN THE MANUFACTURE OF FUEL WATER-GAS AND INCANDESCENT BURNERS FOR SAME,

Report: That there was referred to them—

(1.) His water-gas processes in general;

(2.) His manufacture and utilization of fuel-gas, and

(3.) His forms of incandescent burners for using fuel-gas as a source of illumination.

They did not formally organize for service until some considerable time after the date of appointment. A number of the members of the committee went, by invitation, to Norristown, in May, 1885, to see the works of Prof. Lowe and to inspect his incandescent burners as arranged at his office. We were asked, however, to wait until a more complete exhibit of them could be made at the "Novelties" Exhibition of the FRANKLIN INSTITUTE in the fall. Then, as Prof. Lowe's different exhibits were to be reported upon by several of the groups of judges appointed in connection with this Exhibition, it was thought best not to present anything until their reports had been made.

In February, of this year, Prof. Lowe asked to be allowed to appear before the Sub-Committee and read a paper, in which he presented a statement as to his connection with the water-gas inventions, and dwelt upon its value present and prospective. After this, the committee met at the Hall of the INSTITUTE for consideration of the work allotted to it, and determined upon their general

line of action. But, in the meantime, a committee of the judges of the late "Novelties" Exhibition were preparing a historical review of the whole water-gas subject, which they presented May 1, 1886.

Thus it has happened, that in addition to the abundant literature before available, three reports have been made on this very subject in connection with the late Exhibition of the INSTITUTE, and which are appended to this report for descriptive and other information.

The committee have therefore considered that sufficient reliable data already exist from which to allow them to express an opinion, and have not undertaken any new experimental studies of the processes or inventions

They would therefore state:

(1.) That they agree with the Special Committee of Judges in considering that the combination of the three principles (*i. e.*: of internal combustion, of admitting air and steam to the generator alternately, and of the use of a regenerator "in practicable form for the special purpose of producing a gaseous product suitable either for fuel or illumination), does not appear to have been made or suggested prior to the date of the first publication of what has since come to be known as the Lowe process," and "that this combination of elements constitutes a material improvement in the practice of the art of water-gas manufacture."

(2.) Admitting what no longer admits of dispute, viz.: that gaseous fuel will in the future displace solid fuel wherever the two really come into competition, the committee find that Prof. Lowe's inventions are of very great value in this connection. He produced, at the Exhibition, a fuel-gas containing by volume 3·6 per cent. of CO_2, 42·1 per cent. of CO, 44·5 per cent. of H, and 9·8 per cent. of N, and claims that such gas can be manufactured on a large scale at ten cents per 1,000 cubic feet. This claim the committee have had no opportunity of verifying. Moreover, his various forms of ovens, heaters, ranges, stoves, open-grates, etc., seem to be admirably adapted to serve their intended purposes.

(3.) In testing Prof. Lowe's incandescent burners, made of platinum spirals, for use with non-luminous fuel-gas, the Committee of Judges, at the late "Novelties Exhibition," found an efficiency of 1·40 candles per cubic foot of gas consumed. Prof. Lowe claims that the material does not wear out, and that if bent or broken by accident, they can be replaced at a trifling cost, as the

platinum is always capable of being worked over without loss. They certainly gave a pleasing and agreeable light, as exhibited at the late Exhibition.

The Sub-Committee would, therefore, recommend that the ELLIOT CRESSON MEDAL be awarded Prof. Thad. S. C. Lowe, for his great services to the cause of gas-lighting in connection with his water-gas process, and for his improvements in the manufacture of fuel-gas, and of apparatus for utilizing the same for a variety of purposes.

SAMUEL P. SADTLER, *Chm.*,
GEORGE A. KOENIG,
LEWIS M. HAUPT,
WM. H. WAHL,
OTTO C. WOLF,
HENRY PEMBERTON, JR.,
PEDRO G. SALOM,

Sub-Committee.

Adopted July 7, 1886.

H. R. HEYL, *Chm. Committee on Science and the Arts.*

Franklin Institute.

[*Proceedings of the Annual Meeting, held Wednesday, January 19, 1887.*]

HALL OF THE INSTITUTE, January 19, 1887.

COL. CHAS. H. BANES, President, in the Chair.

Present, 105 members and eight visitors.

Number of new members added since last meeting, eleven.

Reports were presented from the Board of Managers and various Committees, as follows:

ANNUAL REPORT OF THE BOARD OF MANAGERS FOR THE YEAR 1886.

The Board of Managers of the FRANKLIN INSTITUTE of the State of Pennsylvania for the Promotion of the Mechanic Arts, respectfully presents the following report of the operations of the INSTITUTE for the year 1886.

MEMBERS.

Membership at the close of 1886,	2,257	
Number of new Members elected, who have paid their dues,	87	
		2,344
Lost by death or resignation,	63	
Dropped for non-payment of dues,	59	
		122
Total membership at close of 1886,		2,222

FINANCIAL STATEMENT.

Receipts.

Balance on hand January 1, 1886,		$810 78
Exhibition of 1884,	$18 26	
Exhibition of 1885,	393 96	
Exhibition of 1885. Net amount from sale of property after deducting expense of clearing ground and fencing the lot,	3,184 32	
Received from Guarantee Fund on account of loss incurred by Exhibition of 1885,	5,130 49	
Cash from sale of securities,	10,000 00	
Cash from other sources,	12,480 11	
		31,207 14
		$32,017 92

Payments.

Committee on Publication,	4,117 33	
Publication of Reports,	698 95	
Exhibition of 1885,	2,628 93	
Paid on account of temporary loan,	10,000 00	
Interest on temporary loan,	514 76	
Endowment of Memorial Library (invested),	902 70	
Other expenditures,	12,054 30	
		30,916 97
Balance on hand December 31, 1886,		$1,100 95
There still remains to be collected of the Guarantee Fund,	1,717 78	
Remaining unpaid on temporary loan,	*5,000 00	

LIBRARY.

During the year 1886, there were added to the Library 1,325 bound volumes, 512 unbound volumes, ninety-six maps and charts, and 1,817 pamphlets, making a total of 3,754 additional titles. Although these figures fall below those of 1884, when the Memorial Library was added, and 1885, in which 1,300 volumes were added by gift of the heirs of the late Prof. Robt. E. Rogers, the exhibit is a highly creditable one. The whole number of books bound and unbound, in the Library, December 31, 1886, was 27,998. This is exclusive of pamphlets in the main and pamphlet libraries, the number of which is between 8,000 and 9,000.

The catalogue of the pamphlets was completed during the year, and is now accessible for reference. The lack of accommodation, for the proper display and accessibility of the volumes in the Library, so frequently referred to in

* The INSTITUTE has invested funds to the amount of about $30,000, the income of which is available for the general purposes of the INSTITUTE. It should be said, however, that the income from this and from all other sources, for a number of years, has not been sufficient to meet the expenses.

previous reports, was felt more severely, although an attempt to remedy it has been made by removing a considerable number of volumes to the third story.

Additional details appear in the report of the Library Committee.

THE JOURNAL.

The JOURNAL was more than self-supporting during the past year, and has advanced both in the value of its contents and the amount of its business The index is substantially completed, and arrangements for its publication during the present year are now being made, which, it is expected, will be successful.

The Committee on Publication has succeeded in obtaining the voluntary services of a number of collaborators, with whose assistance, it is reasonable to expect, that the usefulness of the JOURNAL will be notably increased. The Board of Managers takes this opportunity to commend the JOURNAL to the members of the INSTITUTE, among whom its circulation is not as large as it should be. It is worthy of a generous support.

LECTURES.

The following Lectures were approved and delivered during the past year. By Dr. Henry F. Formad, *one*, on "Germs, their Influence on Health;" Mr. M. N. Forney, *one*, "The Evolution of the American Locomotive;" Prof. S. T. Sadtler, *one*, on Coal-tar Distillation;" Col. Wm. Ludlow, *one* on "Water-Supplies of Cities;" Col. Geo. E. Waring, *one*, on "Sanitary Care of Cities;" Mr. John Hartman, *one*, on "Blast Furnace Construction;" Mr. C. J. Kintner, *one*, on "The United States Patent Office Historical Electrical Apparatus;" Mr. Oberlin Smith, *one*, on the "Flow of Sheet-Metal in the Drawing Process;" Mr. Jas. Christie, *one*, on "Elementary Problems of Bridge Construction;" Mr. T. C. Search, *one*, on the "Technology of Worsted Manufacture;" Prof. M. B. Snyder, *one*, on "The Relations of Pure Research to the Electrical Exhibition;" Mr. Rudolph Hering, *one*, on "Sanitary Plumbing;" Mr. C. J. Hexamer, *three*, on "Petroleum and its Products;" Mr. Carl Hering, *two*, on "Dynamo-Electric Machinery;" Captain O. E. Michaelis, *one*, on "Electro-Ballistics;" Prof. De Volson Wood, on "The Education of the Mechanical Engineer;" Prof. Persifor Frazer, *four*, on "Elementary Chemistry;" Mr. E. A. Gieseler, *one*, on "The Illumination of Maritime Coasts;" Mr. J. Luther Ringwalt, *two*, on "The Development of Transportation Facilities in the United States;" Mr. S. Lynwood Garrison, *one*, on "The Microscopic Structure of Iron and Steel;" Prof. N. A. Randolph, *two*, on "Life and Death;" "Thought and Sleep;" Prof. Cleveland Abbe, *one*, on "Popular Errors in Meteorology;" Mr. Chas. A. Ashburner, *one*, on "Natural Gas;" and Prof. Albert R. Leeds, *one*, on "The Purification of Water-Supplies."

Thirty-two lectures are included in the foregoing list and many of them were of a high order of excellence and by gentlemen of eminence, of whom a number were non-residents.

The attendance, however, save in exceptional instances, was not notably greater than in previous years.

This indifference on the part of the members is somewhat discouraging to the Committee on Instruction.

The same plan respecting the issue of free tickets to members for distribution, that has been in operation for several years, was adhered to, and it appears to give general satisfaction.

DRAWING SCHOOL.

The Board refers with satisfaction to the continued efficient management of the Drawing School. The number of pupils in attendance was well up to the average of former years.

The attendance at Spring Term, 1886, was, ...	175
The attendance at Fall Term, 1886, was, ...	197
Whole number for the year, ...	372
An increase over the previous year, of, ...	39

COMMITTEE ON SCIENCE AND THE ARTS.

This Committee has been unusually active during the year 1886, owing to the large number of cases referred to it, by the judges of the "Novelties" Exhibition.

Reports were made upon forty-one cases; in nine of which the award of the Elliot Cresson Medal was recommended, and in ten, the award of the John Scott Legacy Premium and Medal. Three protests were entered against these recommendations, of which one was sustained, one was dismissed as immaterial, after due consideration, and one is still under consideration.

Six recommendations for the award of the Elliot Cresson Medal were reported to the INSTITUTE and were approved, after due advertisement in the JOURNAL. Six recommendations for the award of the John Scott Legacy Premium and Medal were similarly reported, all of which were approved, respectively, by the INSTITUTE, and by the Board of City Trusts. In one case, the Committee awarded a Certificate of Merit.

The amended By-Laws involve certain changes in the constitution of this Committee, which, it is anticipated, will increase its usefulness. Commencing with the year 1887, the Committee will consist of forty-five members, elected by the INSTITUTE. During the fifty-two years of its existence as a volunteer body, it has acted upon 1,368 subjects. While it would be exaggeration to say that it has not occasionally committed errors of judgment, its work, taken as a whole, has been highly creditable and useful.

SECTIONS.

The Chemical and Electrical Sections of the INSTITUTE have held regular meetings during the past year, and the attendance indicated a lively interest in their work. Several papers of importance were presented and discussed at the meetings and have been published in the JOURNAL, and a number of subjects have been investigated and reported upon at the solicitation of the Committee on Science and the Arts. Both sections exhibit a substantial increase of membership. The details of their work will appear in their Annual Reports, to which the Board refers.

THE EXHIBITION OF 1885 AND THE GUARANTEE FUND.

After the close of the last exhibition, it was deemed inadvisable to hold another upon the location in West Philadelphia.

The Committee was authorized to sell the building, fixtures and material, and after paying the expense of clearing the ground and fencing the lot, to apply whatever sum remained toward any financial deficiency. After this had been done, a careful statement was prepared and reported to the Board, manifesting a loss, by the Exhibition of 1885, of about $7,000. To meet this deficit, it became absolutely necessary to call upon the subscribers to the Guarantee Fund for their proportionate contributions to the loss. The responses to this call in the large majority of cases have been promptly made, there is, however, a balance not yet received of $1,717.78.

REORGANIZATION AND FUTURE WORK.

Early in the year, a committee was appointed by the INSTITUTE, consisting of Messrs. C. H. Banes, Chairman, Chas. Bullock, J. Vaughan Merrick, Isaac Norris, Jr., Wm. Sellers, Wm. P. Tatham and John J. Weaver, to take into consideration the future work of the INSTITUTE, and to suggest plans or methods for extension. This committee had a number of meetings, and gave much time and thought to the work entrusted to it. As a result of its report, the INSTITUTE made a number of changes in the By-laws, the most radical of these being the creation of a Board of Trustees, in whom the property of the INSTITUTE shall be vested—the Trustees to be elected, partly by stockholders and partly by the Board of Managers, and to be self-perpetuating. Another important change was made in the manner of selecting the members of the Committee on Science and the Arts. Some valuable suggestions have been made by members of the INSTITUTE in reference to the selection of a proposed site for a new and commodious building suited to its increased library and work.

The movement in this most important matter has been deferred by the Board during the deliberations of the committee, but it is to be hoped may commence at once and be pushed with that intelligence and vigor necessary to command the success it deserves.

Respectfully submitted, C. H. BANES, *President.*

The Committee on Library presented the following report:

THE COMMITTEE ON THE LIBRARY respectfully reports, that the Library of the INSTITUTE has received from the Committee and the Librarian the attention demanded by so valuable a collection of literature pertaining to the arts and sciences. The want of proper space for the classifying and safe-keeping of the books has been a source of solicitude to the Committee, and the accumulation of duplicate volumes induced the Committee, during the past year, to print in pamphlet form a complete list of duplicates. This list was distributed widely to libraries throughout the country, and has resulted in effecting the sale of 336 volumes and pamphlets for the sum of $118.15, and the exchange of 1,464 volumes and pamphlets—for 567 volumes and pamphlets,

valued at $466.49. A large number of duplicates yet remains for sale or exchange. The additions to the Library during the past year are as follows:

Volumes, bound,	1,325
Volumes, unbound,	516
Pamphlets,	1,817
Charts and maps,	96
Total,	3,754

Total number of volumes in the Library, exclusive of pamphlets, December 31, 1886, 27,998. The pamphlet collection in the Library is large and valuable, nearly all of them have, during the past year, been classified and arranged in paste-board cases, to admit of more ready reference. The introduction of incandescent electric lights into the Library will, it is hoped, prove acceptable to all who have occasion to use the Library at night.

CHARLES BULLOCK,
Chairman of Committee on Library.

Foregoing reports were accepted and ordered to be placed upon the minutes.

Annual Reports were presented from the Chemical and Electrical Sections, which were accepted and ordered to be filed.

The Secretary presented his report, which comprised an Annual Review of the Progress of the Arts and Manufactures. The report was ordered to be printed, and a copy sent to each member, together with a copy of the Report of the Board of Managers.

The tellers of the Annual Election made their report, whereupon the President declared the following to be elected, as indicated below:

For President, (to serve one year,) JOSEPH M. WILSON; for Vice-President, (to serve three years,) CHARLES BULLOCK; for Secretary, (to serve one year,) WILLIAM H. WAHL; for Treasurer, (to serve one year,) SAMUEL SARTAIN; for Managers, (to serve three years,) CHAS. H. BANES, CYPRIEN CHABOT, WASHINGTON JONES, EDWARD LONGSTRETH, ISAAC NORRIS, JR., ALEX. E. OUTERBRIDGE, THEO. D. RAND, COLEMAN SELLERS; for Auditor, (to serve three years,) WM. B. COOPER.

For members of the *Committee on Science and the Arts:*

Bilgram, Hugo, mechanical engineer.
Chambers, Cyrus, machinist.
Chabot, Cyprien, machinist.
Cheney, Luther L., machinist.
D'Auria, Prof. L., civil engineer.
Eastwick, J. H., chemist.
Emanuel, J. M., engineer U. S. N.
Estrada, R, mechanical engineer.
Faught, L. R., machinist.
Gieseler, E. A., light-house engineer.
Greene, Prof. W. H., chemist.
Hill, Rufus, R. R. master mechanic.
Howard, C. W., machinist.
Hall, Prof. L. B., chemist.
Haug, John, marine architect and engineer.
Haupt, Prof. L. M., civil engineer.
Heyl, H. R., machinist.
Ives, F. E., photographer.

Koenig, Prof. Geo. A., metallurgist.
LeClere, Francis, mechanical engineer.
Le Van, W. B., machinist.
Longstreth, Edward, machinist.
McAllister, W. M., optician.
Marks, Prof. Wm. D., mechanical engineer.
McDevitt, Wm., insurance expert.
Marshall, Samuel R., machinist.
Orr, Hector, printer.
Outerbridge, A. E., assayer.
Perkins, Geo. H., oil-refiner.
Pistor, Philip, draughtsman.
Pemberton, H., Jr., Chemist.
Randolph, Prof. N. A., M. D.
Ronaldson, Chas. E., mechanical engineer.
Rutter, Chas. A., draughtsman.
Shaw, Thomas, machinist.
Spellier, Louis H., electric clocks.
Shain, C. J., philosophical instruments.
Scott, E. Alexander, telegrapher.
Salom, Pedro G., chemist.
Sellers, Coleman, mechanical engineer.
Sartain, Samuel, engraver.
Sadtler, Prof. S. P., chemist.
Search, T. C., textile manufacturer.
Wiegand, S. Lloyd, machinist.
Wahl, Dr. Wm. H., Secretary FRANKLIN INSTITUTE.

Whereupon the meeting was adjourned.

WM. H. WAHL, *Secretary.*

BOOK NOTICES.

THE TECHNO-CHEMICAL RECEIPT BOOK. By Wm. T. Brannt, and Wm. H. Wahl, Ph.D., Secretary of the FRANKLIN INSTITUTE, Philadelphia. Henry Carey Baird & Co. London: Sampson Law. 1886. 495 pp.

This work, edited as it is by an able, practical chemist, fills a long-felt want, in that it places before the public, in a reliable and authoritative form, several thousand receipts covering the latest, most important and most useful discoveries in chemical technology and their practical application in the arts and industries.

Dr. Wahl's facile pen has been put to good use in the preparation of such new matter as has been necessitated for the greater usefulness of the book in America, and shows itself in the clear, precise and intelligent directions given in those receipts or processes that he has re-written, as well as in his editorial supervision of the entire work.

Good judgment has been displayed in the omission of the theoretical reasoning and historical detail that are too frequently permitted to encumber works of this character.

The alphabetical index is not alone relied on to enable the reader to intelligently use the work, but is supplemented by an unusually full index as well as a copious table of contents.

We feel confident that the book will be fully appreciated by those to whom it is addressed. E. J. H.

THE FIGURE OF THE EARTH. By Frank C. Roberts, C.E. Science Series. New York: D. Van Nostrand. 1885. pp. 95.

The object of the publication, as stated in the preface, is to place before

the public valuable historical data relating to the figure of the earth, as well as to arrange in a compact form the more important mathematical principles for the deduction of the figure of the earth upon the spheroidal hypothesis. The book is clearly written and will doubtless prove of value to those interested in the topic to which it relates. E. J. H.

FORESTRY IN NORWAY. By John Croumbie Brown, L.L.D. Edinburgh: Oliver & Boyd. 1884. 227 pp.

This work was put into book-form by the author from a series of popular lectures.

The general interest manifested in intelligent forestry laws has naturally attracted considerable attention to all publications tending to throw light on the same, and we feel assured that the special student of forestry will find in this volume much of interest and value.

Treating, however, as the writer does, of a country rich in the diversity of its physical features, it will probably prove especially interesting, not only to the student of physical geography, but to the general public as well.

The important questions of forest devastation and remedial measures are treated in separate chapters. The feeling as regards the fact of these topics is thus referred to: "Notwithstanding the great recuperative power manifested by Norwegian forests, of which mention has been made, they are, under the excessive drain made upon them in districts favorably situated for the prosecution of trade in timber, being greatly impoverished. Of this, there are indications in more than one of the official reports mentioned in connection with the information given in a previous chapter relative to the geographical distribution of different kinds of trees in Norway."

As to the future, quoting from another publication, the book says: "Large forests cannot be expected in this country, owing to the natural formation, which is mountainous, and greatly intersected by fiords; moreover, the narrow valleys are cultivated, and the mountain-sides often nearly bare rock. The inhabitants are often in want of fuel; turf also being rare. Even in the lower districts, the mountains rise above the forest line, and on the coast the inhabitants and sea-breezes have almost completely destroyed all the forests, which existed in earlier times."

Speaking of remedial measures, the necessity for replanting is of course insisted upon. The cost of fences, in order to protect the young trees from the sheep, is too great in most districts to permit the inhabitants from doing much in this direction. Government aid is therefore requested. E. J. H.

TOPOGRAPHICAL DRAWING, ETC. By Lieut. Henry A. Reed. New York: John Wiley & Sons. 1886.

Here is a work which bears the impress of careful preparation, and, upon examining it, we find it full of the details of the subject of which it treats. It is as complete a treatise on topographical drawing as could be desired by an aspiring student. To the practitioner also it is useful, and would prove an acquisition to his library of reference.

Among other interesting matters, it contains the description of a method

of rapidly coloring topographical sheets, with the object of bringing into relief the shape of the ground. Although this embellishment is not absolutely necessary to enable an engineer to locate a proposed work on a topographical map, yet it helps the operation more than is generally supposed in the profession. Plain contours do not speak clearly to the eye, however useful they may prove to the reasoning faculties; but when they are tinted to proper degrees, the eye and mind work more in harmony. In most offices, the time and expense of finishing a map in style are items of some importance; and seldom is any æsthetic inclination allowed headway. But the rapidity with which topographical maps may be tinted should produce change of opinion in regard to their embellishment.

When the art of surveying shall be better practised among us, and railway and city plans become more accurate, a tendency to embellishment will naturally arise, in virtue of the artistic impulse of humanity to adorn that which is worthy of its respect. Moreover, a certain artistic treatment should always accompany a plan of whatever description. To illustrate: Suppose a map of this state were contemplated, of a scientific character equal to that of the great map of France, would it not be worthy of the most elegant finish? Certainly! On the same principle a *good* map of a large city, and of an important railway, deserves each its special treatment—not of as high quality, probably, as a state map, yet none the less of a pleasing nature.

To the engineer who wishes to carry into effect these ideas, and to look into other interesting points bearing on topographical drawing, we can recommend, without reservation, Lieut. Reed's work. E.

SCIENTIFIC NOTES AND COMMENTS.

PHYSICS AND ASTRONOMY.

RECENT ADVANCES IN METEOROLOGY.—The United States Signal Service merits the thanks of the student of meteorology, by its publication of *Recent Advances in Meteorology*, by William Ferrel, M.A., Ph.D. The volume, 440 pp., is published under the general title, *Annual Report of the Chief Signal Officer of the Army to the Secretary of War*. 1885. Part II. Appendix 71.

The ability with which Dr. Ferrel handles his subject, the clearness and terseness with which he treats it, and the comparatively extended bibliographic research upon which he bases it, will, we think, cause this publication to rank among the most valuable yet issued by the Signal Service.

The volume, as its title indicates, treats of recent advances in meteorology, employing the word recent to embrace those of the last quarter of a century. These advances are presented in logical sequence, and justly entitle the work to be ranked, as its author claims for it in his preface, as "A text-book of the higher meteorology." Where necessary, for the fuller elaboration of some of the topics discussed, the author makes free and extended use of mathematical analysis.

The book is arranged under five chapters, viz.: The Constitution and Physical Properties of the Atmosphere. Chap. II, Temperature of the Atmosphere and Earth's Surface. Chap. III, The General Motions and Pressure of the Atmosphere. Chap. IV, Cyclones. Chap. V, Tornadoes. Each chapter is discussed under numerous sections and sub-sections.

Advances in meteorological science have been so rapid since simultaneous observations, over extended areas, have been made by different Governments, that many of the statements made by Dr. Ferrel, though in reality comparatively old, may nevertheless be novel to many of our readers. We will, therefore, call attention to some of the more interesting of these, without reference to the extent of their claims to novelty.

Departing, however, from the methods usually followed in a review, we will make such condensed statements of meteorological topics treated by the author, or suggested by the context, as we believe may prove of general interest.

The relative proportion of the oxygen and nitrogen of the atmosphere have not varied apparently since the analysis of Regnault, in 1848. The widest variations of the oxygen were included between the limits 20·9 per cent. to 21·0 per cent. The lowest percentage of oxygen—20·3—is found principally in warm climates. The percentage of oxygen is least for the equatorial, and greatest for the polar winds.

A slight decrease exists in the percentage of oxygen in the highest strata of the atmosphere. Only a slightly greater percentage of carbonic acid is found in the air of large cities than in the open country. The proportion does not vary appreciably with the altitude.

Ozone, or tri-atomic oxygen, is to be properly regarded as a general constituent of the atmosphere, since it not only is always to be found in the air, but it also exists therein in measurable quantities.

The arrangement of the constituents of the atmosphere through the agency of diffusion, may be discussed both in accordance with Dalton's theory, and with the kinetic theory of gases. As regards the aqueous vapor of the air, the fact that it is continuously passing from the vaporous to the liquid state, and back again, at different rates, and at different times and places, causes the distribution of this constituent of the atmosphere to be less regular than the other constituents, and leads to grave errors where the amount of aqueous vapor in the atmosphere over extended localities, is deduced from the observed tension at any given locality.

Diffusion according to the kinetic theory of gases is thus lucidly stated. "According to this theory the expansive force and tension of a gas arise from the constant motion and encounters of the molecules flying with great velocity and, on account of the numerous encounters and deflections, in all directions. If the gas is more dense in any region than in neighboring regions, the outward expansive force from this region is greater than the counteracting force toward it, and more molecules pass out than into it, until uniformity of density is established, or, when there is an external force acting in one direction, until an arrangement takes place that makes the tension of all parts exactly equal to the pressure arising from the external force."

The effect, both of Dalton's theory of diffusion, and of the kinetic theory of gases, as regards the final state of the mixture, is the same: the only difference is as to the rates at which the mixture is effected.

Had our atmosphere a constituent of very small density, such for example as hydrogen gas, although the lower strata would contain such rare gas, its tendency would be to rise up far enough above the others so that at certain altitudes it would exist free and separate from all the other constituents. The sun's atmosphere, which, as observed from the earth, consists of nearly pure hydrogen, probably contains in its lower strata an atmosphere of far denser gases.

The diffused light and heat of the sky are due to reflections and re-reflections of the light passing through it. To these irregular reflections are due the visibility of bodies not placed in the direct light, the continuance of twilight, the failure to obtain total darkness at the centre of the shadow during a total eclipse of the sun, and the fact that the greatest cold of the night occurs not directly after midnight but shortly before sunrise.

In clear weather, when the transparency of the air is great, the irregular reflection is small, and the light towards the blue end of the spectrum only is reflected, consequently the color of the sky is a very dark blue. As the atmosphere becomes less transparent, the sky grows first bluish, and afterwards, when all the colors are reflected, of a whitish tinge.

The idea advanced by Tyndall that the diathermancy of the atmosphere is dependent almost entirely on the quantity of aqueous vapor it contains is now to a great extent discredited. The diathermancy would appear to depend not so much on the actual as on the relative humidity, and is greatest when the air is near its point of saturation, whether the actual quantity it then contains is great or small.

Clouds may exist in air unsaturated with moisture if dust-particles be present. The cause is to be ascribed to the lower temperature of the dust-particles due to their higher radiating power than the air, rather than to any affinity or attraction such solid particles have for the vapor.

The great differences in temperatures that would naturally exist between the lower and upper strata of air are lessened by the evaporation of moisture near the surface, which lowers the surface temperature, and its condensation in the upper regions which are thereby heated. Hence the difference between the upper and the surface temperature is less in the equatorial regions where the evaporation and condensation are greatest.

No considerable secular change of temperature appears to have taken place over the earth's general surface for many centuries past. Hence no marked change for extended periods in the intensity of the solar-radiation appears to have been probable. Periodical changes in the sun's surface, however, do occur, and such changes probably influence the mean annual temperature of the earth's surface. Proofs are yet wanting, to show that such periodical changes in the solar-surface, such, for example, as the eleven-year sun-spot period, have produced any appreciable influence on the earth's surface temperature.

Yakutsh, in Siberia, has heretofore been credited with possessing the

lowest mean annual temperature of any explored region of the earth. According to Woeikoff, however, the severity of its winters is far less than that of Werkhojansk, which has an observed mean annual temperature for the month of January of — 55°·2 F. as against — 41°·4 F. for Yakutsh. The excessively low temperature of Werkhojansk is local and extends to but a comparatively limited distance around. Its cause is to be found in the fact, that during calm, clear nights, the valleys are colder than the surrounding high lands, since the cold air sinks down and collects in the valleys.

According to Hamberg, during the night, the temperature of the strata of air very near the earth's surface increases from the surface upwards, and continues to do so until about two hours after sunrise. E. J. H.

THE NUMBER OF STARS IN OUR NEBULA. (*L'Astronomie*, **5**, 406.)—Upon data furnished by observations, M. Gustave Hermite has established two very important laws in regard to the number of stars in our nebula, and the total amount of light we receive from the various classes of stars of different magnitudes.

By the first law, the successive number of stars of first, second, third, etc., magnitudes, follow an increasing geometrical progression of which the first term is 19, and the ratio = 3.

By the second law, the amount of light received from the successive orders of stars of first, second, third, etc., magnitudes, follow also an increasing geometrical progression of which the first term is 19, and the ratio $= \frac{3}{2{\cdot}56}$.

By the aid of these laws, and the assumption that the total amount of light the earth receives from the stars is one-tenth of that of a full moon. M. Hermite concludes that our nebula contains 6,000,000,000 stars. L. d'A.

A. RICCÒ and A. MOSCARI, of the Royal Observatory of Palermo, publish (*Mem. della Soc. degli Spettroscopisti Italiani*, Vol. **15**, *Disp.* 7*a*), their work on "Determining the Dimensions and Positions of the Solar Protuberances in the years 1882–83–84." "It is highly important," say they, "to determine the law, which the variation of the mean latitude of the solar-protuberances, obeys; also, to see if there is any relation with the period of frequency of solar-protuberances, as well as with the law of Spörer for spots." The short period yet covered does not permit any satisfactory deductions; but this first attempt at accurately stating both the position and size of solar-flames may lead to very important discoveries in solar meteorology. M. B. S.

THE MEAN MINOR PLANET.—A. Svedstrup, under the title "*Les petites planètes entres Mars et Jupiter.*" *Une recherche statistique*), publishes in the *Astronomische Nachrichten*, Nos. 2740–41, the results of a laborious discussion, for which he received the gold medal from the Royal Danish Academy, of the elements of the planet that would on the average represent the Asteroid group. It was Olbers, who first proposed to account for the minor planets by means of the hypothesis of the explosion of a single planet, but the weakness of this hypothesis having been shown, the one now generally adopted is that according to which the small planets are due to simultaneous condensation at several points of the ring or system of rings provided by the

nebular hypothesis. It is with a view both of testing this hypothesis and of throwing light on the geometric arrangement, which the orbits of these small planets present, that a number of statistical researches on the ring constituting the minor planets have been undertaken. D'Arrest found that large eccentricities of orbit were generally combined with great inclinations to the ecliptic; and that the nodes and perihelia seemed to have a tendency to accumulate in certain directions. Newcomb demonstrated the latter as an effect of perturbations. Besides, Kirkwood called attention to the fact that if these planets are grouped according to their mean distances, there will be intervals relatively vacant at such mean distances as to have periods of revolutions in simple ratios to those of the larger planets. Such is in effect a summary of the author's reasons for undertaking the work. For the elements of the mean planet, we must refer to the original article, only stating that the mass assigned would make it of a magnitude of 6·7 in opposition. M. B. S.

ASTRONOMICAL JOURNALS IN AMERICA.—It is gratifying to note that America is once again to have an astronomical periodical, devoted to the advancement of the science itself. We refer to the recent resumption of the publication of the *Astronomical Journal*, by Dr. B. A. Gould. When in July, 1861, the *Journal* was, on account of the war, discontinued with the words: "It is my fervent hope to resume the publication of the *Journal* at an early day, by commencing the seventh volume soon after the suspension of the present insurrection," Dr. Gould could scarcely have imagined that a full quarter of a century would intervene before his "fervent hope" would be realized. It is creditable to his pertinacity of purpose, as well as to his interest in the furtherance of astronomical science, to have again undertaken so important a task. We should remember, too, that the major portion of these years have been given by Dr. Gould to the advancement of American astronomy in connection with the Argentine National Observatory, and in a manner that has challenged the admiration of the scientific world. The long years of experience acquired in the science will no doubt contribute to the character of the *Journal*, and, we hope, secure for it permanence of publication. "The plan," says Dr. Gould, "is to continue the *Journal* in the same form and spirit as before, and under essentially the same conditions. These imply a devotion to the advancement, rather than to the diffusion of astronomical knowledge, yet without disregarding the importance of a prompt announcement of important discoveries. They imply also the dissemination of original researches only, and with the understanding that the publication of statements or opinions is in no case to be interpreted as an endorsement of them by the editor."

It is impossible to estimate the stimulus that a journal of this character may give to astronomical science in this country. It provides a ready means for the publication of researches likely to go unpublished for years, and it will no doubt also encourage researches and valuable observations, which would otherwise not have been undertaken. Surely, with all the big telescopes and observatories of the United States, it should be possible to associate a journal that would reflect a respectable quality of work. We have no doubt,

however, the *Journal* will flourish, notwithstanding the present number of excellent equipments now in almost total disuse, nor that it will stimulate to the provision of a proper staff of observers for them.

The only other American astronomical periodical, dating back to the time when the *Journal* was published, is the *Astronomical Notices* of Brünnow, published first in 1858, from the Observatory at Ann Arbor. While intended to secure the publication of observations and investigations made at that observatory, he also intended it to furnish reliable ephemerides of newly-discovered comets and asteroids, and invited communications from other astronomers. Unfortunately, it also ended its career about the beginning of the war. Some of the numbers are particularly valuable, and we could wish a republication, in some accessible form, of all the matter of the *Astronomical Notices* not positively unserviceable. The *Notices* cannot now, we believe, be had in complete sets, and yet we cannot well afford to lose the important contributions. It may be here remarked that Drs. Gould and Brünnow were both students under the celebrated Encke, and that the lines of active astronomers in America, nurtured into existence by them, can easily be traced. We hope that the early efforts of these men to create an American astronomical literature may not only be not forgotten, but may in some practical way be made accessible.

A more recent effort is the *Sidereal Messenger*, published by Prof. Wm. W. Payne, Director of Carleton College Observatory. It began with a very popular tone and with very little to recommend it to the attention of scientific men. But it has gradually advanced somewhat in the scientific direction, so that it now occupies a fairly respectable position, with the prospect of serving a very useful purpose in American astronomy. The editor certainly deserves the praise and practical sympathy of all interested in the science for securing so creditable result in the face of much indifference.

The only other American astronomical periodical with which we are acquainted is the *Revista do Observatorio*, a monthly publication of the Imperial Observatory of Rio de Janeiro. It is a publication of a semi-popular character—containing an indication of phenomena, popular discussion of astronomical topics, meteorological papers and notices of astronomical events.

M. B. S.

William Huggins (*Astron. Nach.*, **2,747**), formally announces the apparent failure of his method of photographing the solar corona without a solar eclipse. The plates, taken in England about the time of the eclipse of May 6, 1883, presented, he says, not only a general resemblance to those taken during the eclipse, but showed a remarkable rift, which was the main feature of the corona as photographed at Caroline Island. In the eclipse of August 29, 1886, Dr. Gill, of Cape of Good Hope, found that the plates did not show "the corona cut off partially by the moon in its approach to and passage over the sun." Hence, while expressing inability to explain the early favorable results, Huggins states that the method "would seem to have failed."

M. B. S.

CHEMISTRY.

ON THE MAGNETIC ROTATION OF MIXTURES OF WATER WITH SOME OF THE ACIDS OF THE FATTY SERIES, WITH ALCOHOL AND WITH SULPHURIC ACID; AND OBSERVATIONS ON WATER OF CRYSTALLIZATION. By W. H. Perkin. (*Jour. Chem. Soc.*, **49**, 777).—Taking the molecular rotation of water as unity, this value is found not to be the same as the sum of the values of oxygen and two of hydrogen as deduced from the molecular rotation of other compounds. The lowest value for $H_2 + O$ is 0·645, the highest 0·769, instead of 1·0. So that in hydrated compounds the numbers given might indicate whether they still contained water, or whether the water and the substance with which it was mixed had combined to form new compounds. It is known that on adding water in molecular proportions to certain of the fatty acids and alcohols, changes take place in the volume, density and temperature of the mixture; and since it has been believed that some of the fatty acids do unite with water to form tri-hydric alcohols, their examination appeared to be of special interest. The following are some of the results obtained:

	Magnetic Rotation Calculated.		*Found.*
CH_2O_2,	1·671	2·671	2·666
H_2O,	1·000		
$C_2H_4O_2$,	2·525	3·525	3·554
H_2O,	1·000		
$C_3H_6O_2$,	3·462	4·462	4·512
H_2O,	1·000		
C_2H_6O,	2·780	3·780	3·787
H_2O,	1·000		

From these numbers, it will be seen that these products behave as mixtures of the acids and alcohol and water, and not as though the latter were combined as hydroxyl.

Mixtures of sulphuric acid and water in molecular proportions were now examined, with the following interesting results:

	Calculated.		*Found.*
Sulphuric acid,	2·315	3·315	3·188
H_2O,	1·000		
Sulphuric acid,	2·315	4·315	4·113
$2H_2O$,	2·000		
Sulphuric acid,	2·315	5·315	5·064
$3H_2O$,	3·000		

The increase in rotation, due to the water added, is in the first case 0·825, in the second 0·925, in the third 0·951, instead of 1·0; hence we have the indication that the largest amount of combination takes place when the first molecule is added, and it would appear that sulphuric acid with one molecule of water forms the compound $(HO)_4SO$, but that all the acid cannot exist as this without the presence of a large amount of water. Subtracting the value of sulphuric acid from the value of sulphuric acid plus three molecules of water, we obtain,

H_2SO_4 } $3H_2O$ }	5·064
H_2SO_4.	2·315
Influence of 3 molecules of water, ...	2·749

This value is equal to that of two molecules of water + ·749. The author has found that there exists a close analogy between the action of water on an anhydride of a fatty acid and the formation of such a compound as $(HO)_4SO$. Thus:

Rotation of acetic acid 2·525 × 2	= 5·050
Rotation of acetic anhydride	= 4·282
Difference	= 0·768
Rotation of propionic acid 3·462 × 2	= 6·924
Rotation of propionic anhydride	= 6·185
Difference	0·739

Now, it will be seen that these numbers correspond very closely with the residual number obtained above in the case of sulphuric acid, viz., 0749; so that the probability of the compound $(HO)_4SO$, being the result of the addition of water to sulphuric acid, becomes very strong. The author comes to the further conclusion that the relationship of water of crystallization to chemical compounds is purely *physical*. A. G. P.

On the Electrolysis of Hydrogen-Fluoride and on the Properties of Fluorine. H. Moissan. (*Comptes Rendus*, **103**, 202 and 256.)—Early last summer, the author presented to the Académie des Sciences a memoir showing that hydrogen-fluoride is decomposed by an electric current with disengagement of hydrogen at the negative-pole, while at the positive there appears a gas having new properties. The experiments have been continued with gratifying results.

The hydrogen-fluoride used was prepared by heating potassium and hydrogen double-fluoride in a platinum-retort, and condensing the vapors in a platinum-receiver cooled by ice and salt. The potassium hydrogen-fluoride was prepared by Fremy's method, and carefully dried, first at 100° C., then over sulphuric acid and potassium hydroxide in a vacuum. The sulphuric acid and potash in the receiver were changed every day during a fortnight, the fluoride being pulverized in an iron mortar each time, in order to present new surfaces. When the double fluoride is free from water, it crumbles to a powder much less deliquescent than potassium-fluoride, and may then be used for the preparation of dry hydrogen-fluoride.

The dry double-fluoride is introduced into a thoroughly dry platinum-retort, and gently heated for about an hour to drive off remaining traces of water with the first portions of hydrogen-fluoride that are disengaged. The platinum-receiver is then adapted, and the temperature is raised, not enough, however, to cause a rapid evolution of hydrogen-fluoride; all the hydrogen-fluoride now condenses in the receiver, which is cooled by ice and salt. (*Fig. 1.*)*

* We owe the privilege of using these cuts to the courtesy of *The Electrical World*.

The hydrogen-fluoride is then transferred to the platinum U-tube, in which the electrolysis is to take place, and which is provided with fluor-spar stoppers, through which the electrodes pass, and with a platinum delivery-tube

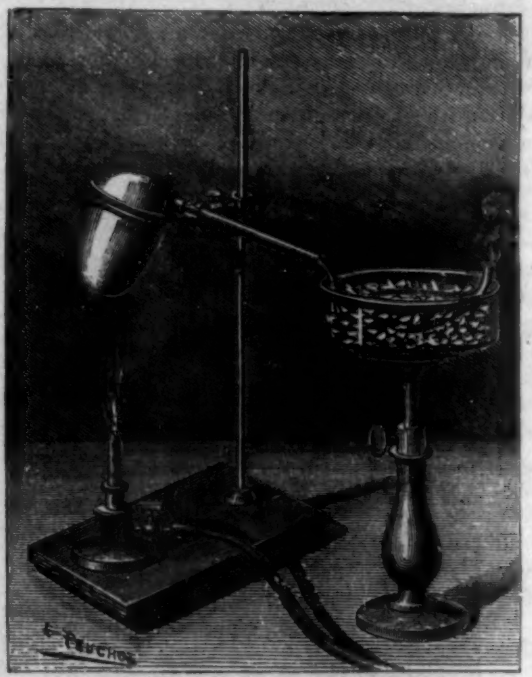

FIG. 1.

on each limb (*Fig. 2*). Both before the introduction of the hydrogen-fluoride and during the electrolysis, this U-tube is cooled in a bath of methyl-chloride,

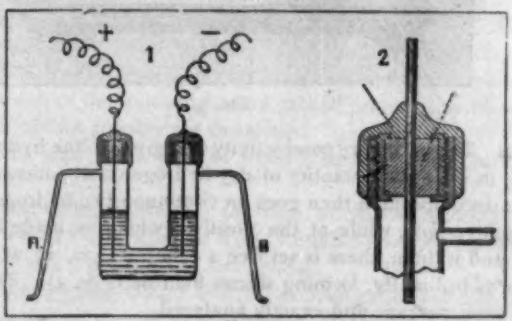

FIG. 2.

boiling quietly at — 23° C. In some experiments, the hydrogen-fluoride was condensed at once in the electrolysis-tube, but as this tube may become

obstructed by the double-fluoride mechanically carried over and dangerous explosions may so occur, this method is not to be recommended. The liquid hydrogen-fluoride may be readily introduced into the U-tube through one of the side-branches.

The current, which served for the decomposition, was derived from a battery of twenty large Bunsen elements, and an ammeter was placed in the circuit. If the hydrogen-fluid contains any water, this is first decomposed, with the evolution of ozone at the positive-pole; but as the last traces of water are decomposed, the resistance of the liquid rises rapidly, and the current of twenty-five ampères is completely arrested when the liquid becomes

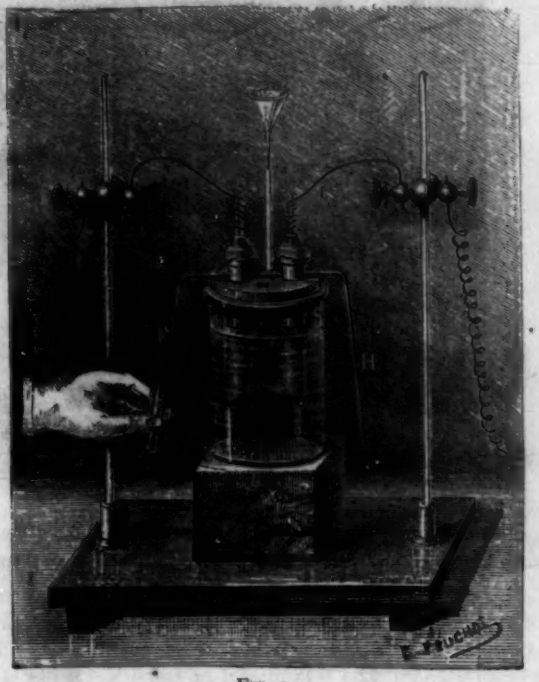

FIG. 3.

anhydrous. The necessary conductivity was given to the hydrogen-fluoride by dissolving in it a small quantity of dry hydrogen and potassium double fluoride. The decomposition then goes on continuously; hydrogen is disengaged at the negative-pole, while at the positive, which is made from an alloy of platinum and iridium, there is set free a colorless gas, in which crystallized silicon burns brilliantly, forming silicon-fluoride (*Fig. 3*). The latter gas was collected over mercury and exactly analyzed.

In the same manner, adamantine boron takes fire, but with more difficulty, probably because of the carbon and aluminium present. Arsenic, antimony, sulphur and iodine combine with the new gas with incandescence,

and water is decomposed by it, with the formation of ozone and hydrofluoric acid. The metals are acted on with less energy, probably because a superficial layer of fluoride is first formed, and this protects the metal from further action; nevertheless, previously-warmed iron and manganese in powder burn with sparks in the gas. Carbon compounds are acted on violently; a piece of cork, held near the delivery-tube from which the gas was escaping, was at once carbonized and inflamed. Alcohol, ether, benzene and turpentine took fire at once on contact with the gas.

When the level of the liquid in the decomposition-tube falls so that the gases are no longer separated, they recombine, even at the low temperature, with a violent explosion.

In order to determine whether the new gas was fluorine or a perfluoride of hydrogen, the delivery-tube from the positive-pole was connected with a platinum-tube containing potassium-fluoride to remove all traces of hydrogen-fluoride, and this with another tube containing a weighed quantity of iron-wire. Arrangements were made for collecting any gas that might escape from the tube containing the iron, and also the gas from the negative-pole. The whole apparatus was then filled with carbon-dioxide, the tube containing the iron was heated to redness, and the electric current was passed while the tube containing the hydrogen-fluoride was cooled to — 50° by forcing a current of air through the bath of methyl-chloride. 0·130 gramme of fluorine was absorbed by the iron, while seventy-eight cubic centimetres of hydrogen escaped from the negative-pole. No gas, except a small quantity of air, could be collected from the tube containing the iron. Since the quantity of iron-fluoride formed corresponded exactly with the quantity of hydrogen collected at the negative-pole, the new gas is unquestionably fluorine.

Operating under favorable conditions, from 1·5 to two litres of fluorine per hour may be obtained by the electrolysis of hydrogen-fluoride.

Fluorine may also be obtained by the electrolysis of potassium and hydrogen double fluoride, fused at 110° C., but the platinum apparatus used is rapidly attacked at this temperature. W. H. G.

Dyes and Coloring Materials of La Plata. (*Textile Manufacturer* **12**, p. 584.)—British Consul Baker, of Buenos Ayres, reporting on the above subject, in addition to an account of several animal and plant dyes, makes special mention of the following wood, which promises to be of value when the resources of that country are developed.

Lapacho (Tecoma asper, Gries). The wood is so hard, that it is used for making cog-wheels.

It contains 7 per cent. tannin, 7·5 per cent. of yellow coloring matter, which crystallizes well, 12·5 per cent. of a less valuable coloring matter which does not crystallize, and 5 per cent. of caoutchouc.

The crystallizable coloring matter, which has been called *lapachic acid*, is prepared by boiling the wood with dilute solution of sodium carbonate, precipitating with hydrochloric acid and purifying by crystallization from alcohol, which leaves it in prismatic crystals, these by sublimation are obtained in form of needles. With stannous chloride, alum or acetate of lead as mordant,

a rose crimson color is produced, with stannic chloride a yellow, and with sulphate of copper, a brown. H. T.

LIQUEFACTION AND SOLIDIFICATION OF HYDROGEN COMPOUNDS.—K. Olsewski (*Monatshefte für Chemie*, **7**, 371) has found that *hydrogen-fluoride* solidifies to a white, crystalline mass at — 102°·5 C: The solid melts at — 92·3.

Hydrogen phosphide liquifies at — 90°, and solidifies at — 133·5. The solid melts at — 132·5, and boils at — 85°.

Hydrogen-antimonide, prepared by the action of dilute sulphuric acid on an alloy of two parts antimony and three parts zinc, only the first portions of gas being collected, solidifies at — 91°·5. As the temperature is raised, it begins to decompose between — 65° and — 56°, antimony being deposited on the walls of the tube; at — 18° this decomposition takes place rapidly. It is not then difficult to understand why such small proportions of hydrogen antimonide are obtained at ordinary temperatures. W. H. G.

THE GRAPHIC EXPRESSION OF THE RELATIONS BETWEEN THE GASEOUS AND LIQUID STATES.—S. V. Wroblewski (*Monatshefte für Chemie*, **7**, 383), proposes for curves of equal density, the co-ordinates being temperatures and pressures, the name *isopyknes*. If a system of isopyknes be drawn for any homogeneous isotropic body, the curves cannot cut one another. Instead of the definition of Andrews, the author proposes that the critical point shall be defined as the critical density, or the smallest density which the substance can have as a liquid. The change of a liquid into a vapor at the critical density cannot take place without an absorption of heat, however small it may be. The disappearance of the meniscus is but an optical phenomenon, showing only that the density of the lower layers of gas is the same as that of the upper layers of liquid, and is not a true index of a critical condition. The paper, which cannot well be condensed, includes the complete isopyknes for carbon dioxide. W. H. G.

ON THE CONSTITUTION OF BENZOL.—Julius Thomsen (*Berliner Berichte*, **19**, 2,944), reviewing the objections to the heretofore proposed structural formula of benzol, shows that all the conditions of the case, including the addition compounds, are met by a formula in which the six carbon atoms occupy the angular terminations of a regular octohedron. In benzol, the atomic unions would be between the extreme atoms—the terminations of the axes—between two adjacent atoms in opposite pairs in a horizontal plane, and between the adjacent atoms in opposite pairs in each of two vertical planes. Each carbon atom would, therefore, be in relations with that diametrically opposite, with one in the same horizontal plane with itself and the centre, and with one in the same vertical plane with itself and the centre. W. H. G.

A LECTURE THERMOMETER.—F. C. Muller (*Berichte*, **19**, 2,175) recommends a large thermometer filled with sulphuric acid, blackened by a little sugar; sulphuric acid expands regularly, and as its coefficient of expansion is three and one-half times as great as that of mercury slight variations of temperature during experiments may be seen by a large class. Successive spaces of ten degrees of the scale, which is placed back of the thermometer, are differently colored, so that the audience can readily read the level of the acid. W. H. G.

Fig. 4.—White Pig Iron.
× 20 diameters.

Fig. 5.—Longitudinal Section of Rolled Bar Iron.
× 45 diameters.

Fig. 6.—Cross Section of Rolled Bar Iron.
× 45 diameters.

Fig. 7.—Weld of Iron and Steel.
× 45 diameters.

Fig. 6.—Cross Section of Rolled Bar Iron.
× 45 diameters.

Fig. 7.—Weld of Iron and Steel.
× 45 diameters.

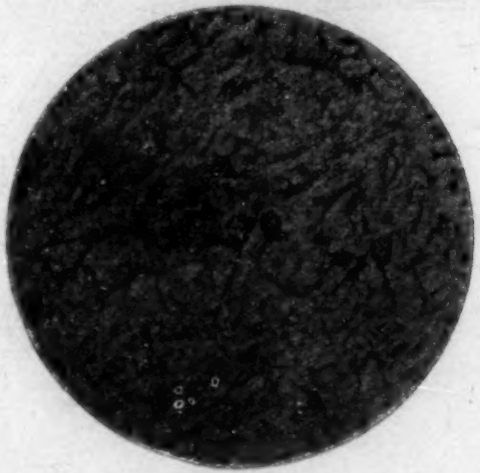

Fig. 2.—Gray Pig Iron.
× 50 diameters.

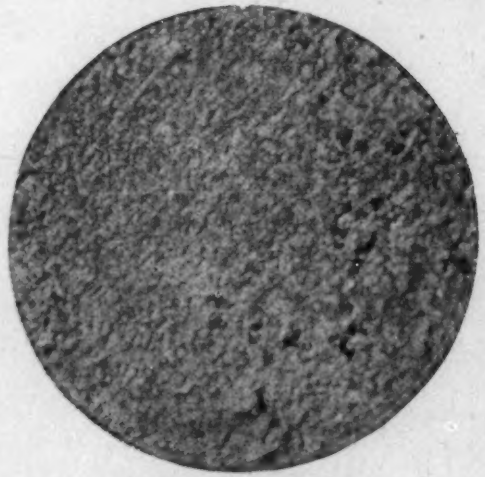

Fig. 3.—Mottled Iron.
× 50 diameters.

Fig. 2.—Gray Pig Iron.
× 50 diameters.

Fig. 3.—Mottled Iron.
× 50 diameters.

Fig. 4.—White Pig Iron.
× 20 diameters.

Fig. 5.—Longitudinal Section of Rolled Bar Iron.
× 45 diameters.

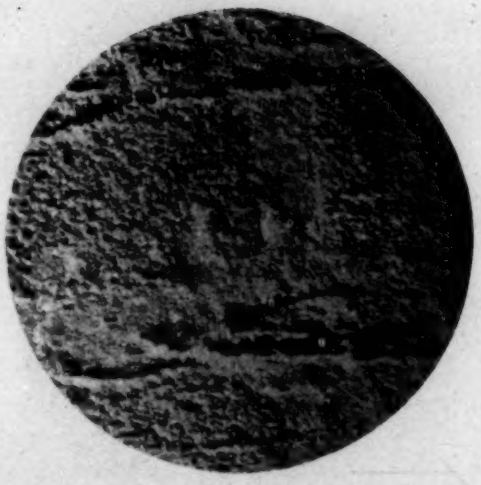

Fig. 9.—Longitudinal Section of a Bessemer Steel Bolt.
× 45 diameters.

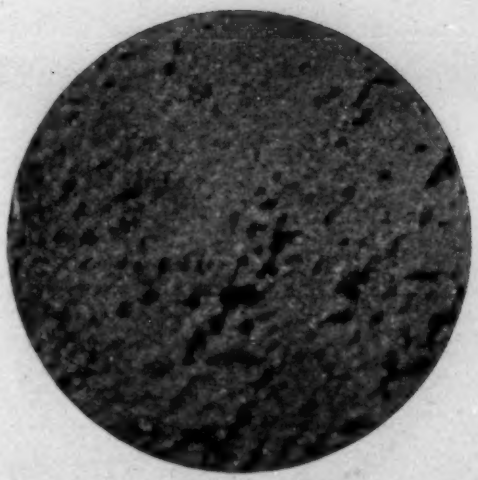

Fig. 10.—Cross Section of a Bessemer Steel Bolt.
× 45 diameters.

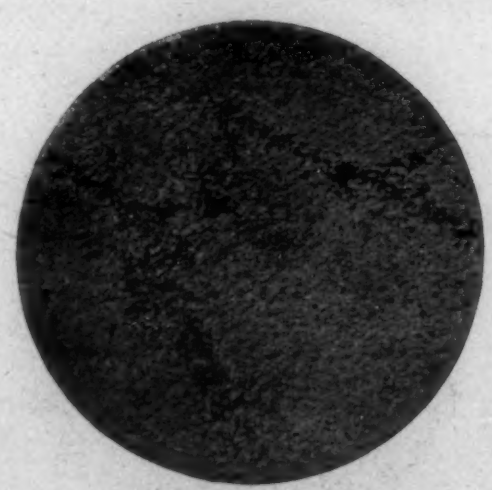

Fig. 11.—Cross Section of a Steel Rail.
× 50 diameters.

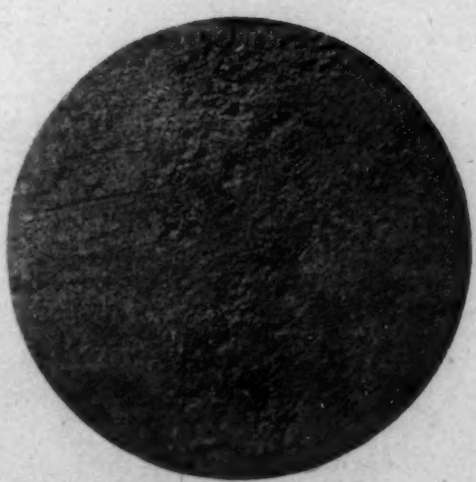

Fig. 12.—Longitudinal Section of a Steel Rail.
× 50 diameters.

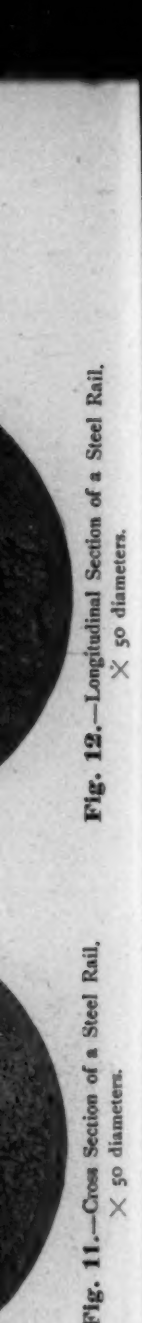

Fig. 12.—Longitudinal Section of a Steel Rail. × 50 diameters.

Fig. 11.—Cross Section of a Steel Rail. × 50 diameters.

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THE MICROSCOPIC STRUCTURE OF IRON AND STEEL.

BY F. LYNWOOD GARRISON, F.G.S.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *Friday, December 10, 1886.*]

LADIES AND GENTLEMEN:—The subject which I am about to bring to your attention to-night, is one of the most interesting developments, which the science of metallurgy has ever made, and although the use of the microscope in the practical metallurgy of iron and steel is yet but in an experimental stage, it promises to increase our knowledge of the properties of metals to a degree that it would be difficult to approximate. Although the ultimate practical value of this subject has been much questioned, one thing is absolutely certain—that with the microscope, we can see vastly more of the structure of the metal than could be seen with the naked eye. We see many things, the existence of which we never before suspected, and, as in the case of the application of chemistry to this same branch of engineering, it is only required that the data so derived should be properly interpreted and applied,